LONDON-WEST MIDLANDS ENVIRONMENTAL STATEMENT

Volume 5 | Technical Appendices

CFA15 | Greatworth to Lower Boddington

Flood risk assessment (WR-003-015)

Water resources

November 2013

VOL 5

ES 3.5.2.15.14

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Department for Transport

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1 Introduction

1.1 Structure of the water resources and flood risk assessment appendices

1.1.1 The water resources and flood risk assessment appendices comprise six parts. The first of these is a route-wide appendix (Volume 5: Appendix WR-001-000).

1.1.2 Specific appendices for each community forum area (CFA) are also provided. For the Greatworth to Lower Boddington area (CFA15) these are:

- a water resources assessment (Volume 5: Appendix WR-002-015);
- a flood risk assessment (i.e. this appendix); and
- hydraulic modelling reports for the Culworth Brook at Lower Thorpe (Volume 5: Appendix WR-004-006), the River Cherwell at Edgcote (Volume 5: Appendix WR-004-007) and the Highfurlong Brook (Volume 5: Appendix WR-004-008)

1.1.3 Maps referred to throughout the water resources and flood risk assessment appendices are contained in the Volume 5, Water Resources and Flood Risk Assessment Map Book.

1.2 Scope and structure of this assessment

1.2.1 This flood risk assessment (FRA) considers the assessment of flood risk in CFA15. The assessment has been carried out in accordance with the requirements of the National Planning Policy Framework (NPPF)[1] which aims to prevent inappropriate development in areas at risk of flooding and to ensure that, where development is necessary in areas at risk of flooding, it is safe without increasing flood risk elsewhere.

1.2.2 The FRA methodology and a review of the relevant local planning policy documents are provided in Section 2 of this report. The design criteria are provided in Section 3, and Section 4 documents the sources of information that have been reviewed. Section 5 provides a description of the planned works within CFA15. Section 6 considers baseline flood risk and the risk of flooding to the Proposed Scheme from all relevant sources. Flood risk mitigation measures included within the Proposed Scheme are detailed in Section 7. The effect of the Proposed Scheme on the risk of flooding is considered in Section 8.

1.3 Location

1.3.1 CFA15 covers an approximately 17km section of the Proposed Scheme in the district of South Northamptonshire. It extends from south of Halse Copse between the settlements of Radstone and Greatworth to the Northamptonshire-Warwickshire county boundary in the north, as shown in Figure 1. The Newton Purcell to Brackley area (CFA14) and the Ladbroke and Southam area (CFA16) lie respectively to the south and to the north. The study area extends to a distance of 1km from the centre

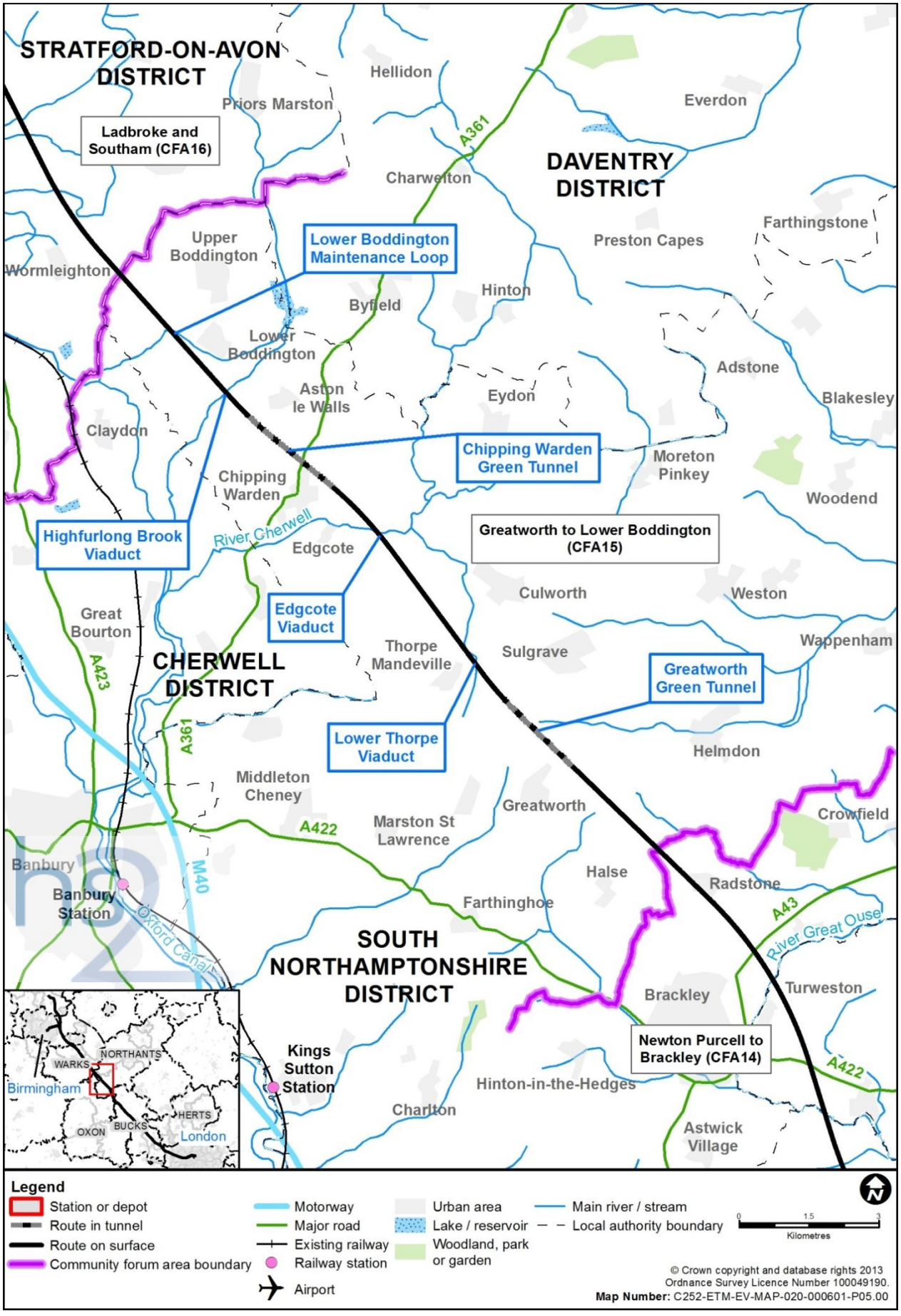
[1] Department for Communities and Local Government (2012), *National Planning Policy Framework*

line of the route and includes the parishes of Greatworth, Helmdon, Marston St. Lawrence, Sulgrave, Thorpe Mandeville, Culworth, Chipping Warden and Edgcote, Aston le Walls and Boddington. It extends from the boundary between Radstone and Greatworth parish in the south-east to the intersection of Boddington, Wormleighton and Stoneton parishes in the north-west. The corresponding council wards are Greatworth, Marston St Lawrence, Thorpe Mandeville, Culworth, Chipping Warden and Edgcote, Aston le Walls and Boddington.

1.3.2 The route will cross a number of primary watercourses within the study area, as identified using the surface water crossing (SWC) references on Map WR-01-022, Map WR-01-023 and Map WR-01-024 (Volume 5, Water Resources and Flood Risk Assessment Map Book), including:

- the Culworth Brook (SWC-CFA15-02 to SWC-CFA15-04);
- the River Cherwell (SWC-CFA15-07 and SWC-CFA15-20) and its tributaries (SWC-CFA15-06 and SWC-CFA15-21);
- the Highfurlong Brook (SWC-CFA15-09); and
- the Boddington Feeder Channel (SWC-CFA15-11).

Figure 1: Greatworth to Lower Boddington area



2 Flood risk assessment methodology

2.1 Source-pathway-receptor model

2.1.1 Flood risk is assessed using the source-pathway-receptor model. In this model individual sources of flooding within the study area are identified. The primary source of flooding is rainfall which is a direct source in the short-term (surface water flooding) and can lead to flooding from watercourses (river flooding) and overloaded man-made collection systems (sewer flooding) in the short- or medium-term. Stored rainfall, either naturally in below ground aquifers and natural lakes or artificially in impounded reservoirs and canals, can lead to flooding when the storage capacity of the system is exceeded. A final source of flooding arises from tidal effects and storm surges caused by low pressure systems over the sea.

2.1.2 For there to be a risk of flooding at an individual receptor there must be a pathway linking it to the source of flooding. The pathways within the study area are assessed by reviewing national datasets that show the spatial distribution of flood risk. The associated risk magnitude is then categorised.

2.1.3 Receptors considered in this assessment include the Proposed Scheme and existing development within 1km of the Proposed Scheme. The Proposed Scheme includes all associated permanent infrastructure. Areas of interest are identified through comparison of the national spatial datasets with the design drawings. Where a risk is identified mitigation is proposed in line with recommendations in the NPPF.

2.1.4 Existing developments within the study area are identified using Ordnance Survey (OS) mapping information. A high-level screening assessment is then undertaken to identify receptors that are within or in close proximity to an area of flood risk via pathways indicated using the flood risk data sources listed below. The vulnerability of each receptor is classified using Table 2 of the NPPF Technical Guidance Document[2].

2.1.5 The assessment then considers the vulnerability of the receptor with reference to the flood risk category of the source using Table 3 of the NPPF Technical Guidance Document and assesses whether the Proposed Scheme has any potential to influence or alter the risk of flooding to each receptor. Where such potential has been identified, mitigation is proposed based on further analysis.

2.2 Flood risk categories

2.2.1 The level of flood risk is categorised by assessing the design elements against the datasets for each source. A matrix showing the flood risk category associated with each flooding source is presented in Table 1.

[2] Department for Communities and Local Government (2012), *National Planning Policy Framework Technical Guidance*

Table 1: Flood risk category matrix for all flooding sources

Source of flooding	Flood risk category				
	No risk	**Low**	**Medium**	**High**	**Very high**
Rivers		Flood Zone 1	Flood Zone 2	Flood Zone 3a	Flood Zone 3b
Surface water	No surface water flooding.	Surface water flooding <0.3m for 1 in 200 years event.	Surface water flooding >0.3m for 1 in 200 years event; and Surface water flooding <0.3m for 1 in 30 years event.	Surface water flooding >0.3m for 1 in 30 years event.	
Groundwater		Very low-low	Moderate	High-very high	
Drainage and sewer systems	No sewer in vicinity of site.	Surcharge point >20m from site and no pathways.	Surcharge point within 20m of site and restricted pathways.	Sewer network crosses site and pathways exist.	
Artificial sources	Outside of inundation mapping/no pathway exists.	Within inundation mapping/ pathway exists.			

2.3 Regional and local flooding planning policy documents

2.3.1 The lead local flood authority (LLFA) for the study area is Northamptonshire County Council (NCC). The recommendations from the Northamptonshire Preliminary Flood Risk Assessment (PFRA)[3], undertaken in accordance with the Flood Risk Regulations 2009[4], have been reviewed in undertaking this assessment. The draft Northamptonshire Local Flood Risk Management Strategy (LFRMS)[5] is at the consultation stage and was published in December 2012.

2.3.2 The local planning authority for the study area is South Northamptonshire District Council (SNDC) and is currently part of the West Northamptonshire Joint Planning Unit (WNJPU). The WNJPU was established to prepare joint development plan documents including the West Northamptonshire Joint Core Strategy[6] and the West Northamptonshire Strategic Flood Risk Assessment (SFRA)[7]. The emergent core strategy is at the consultation draft stage.

[3] Northamptonshire County Council (2011), *Northamptonshire Preliminary Flood Risk Assessment.*
[4] *Flood Risk Regulations 2009* (SI 2009 No.3042). London, Her Majesty's Station Office.
[5] Northamptonshire County Council (2012), *Northamptonshire Local Flood Risk Management Strategy*.
[6] West Northamptonshire Joint Planning Unit (2011), *West Northamptonshire Joint Core Strategy Pre-submission and proposed changes 2012*
[7] Scott Wilson (2009), *West Northamptonshire Level 2 Strategic Flood Risk Assessment*

Northamptonshire Preliminary Flood Risk Assessment

2.3.3 The Northamptonshire PFRA confirms that there are no indicative flood risk areas of national significance within Northamptonshire. Consequently, only Stage 1 of the Flood Risk Regulations 2009 process (i.e. the PFRA) has been completed.

Northamptonshire draft Local Flood Risk Management Strategy

2.3.4 The Northamptonshire draft LFRMS guides the planning process in relation to flood risk across all categories. Areas of particular interest are identified by assigning impact scores across a range of factors (health, social, economic, environment, infrastructure and psychology) for each flood source. The average impact score is used to assign a priority grading to each ward. All wards within the study area have been assigned low priority for groundwater flooding. For surface water flooding all wards have been assigned a high priority except Sulgrave (which falls partially within the 1km buffer north of Thorpe Mandeville) which is assigned very high priority. All wards are assigned a low sensitivity to climate change in relation to both river and surface water flooding.

2.3.5 The Northamptonshire draft LFRMS outlines key policies in relation to development within Northamptonshire. Specific policies of relevance to the Proposed Scheme are:

- Policy 1 – no culverting of watercourses without an overriding need to do so. Where possible, bridges and diversions are preferred. Where culverts are absolutely necessary loss of habitat, pollution, changes in river morphology and loss of amenity space should be mitigated;
- Policy 2 – no introduction of water, increase in flow or flow volume to any watercourse, whether directly or indirectly. All collected surface water should be attenuated at source prior to discharge into local watercourses;
- Policy 4 – no diversion or obstruction of watercourses; and
- Policy 7 – no obstructions within 9m of the edge of any watercourse.

Thames Region Catchment Flood Management Plan

2.3.6 Most water bodies in this area fall within the Thames Region Catchment Flood Management Plan (CFMP)[8] which covers the extent of the Thames basin. The main focus of the plan revolves around the high risk of flooding to key urban centres, the majority of which lie downstream of the study area, and the predicted future increase in flood risk due to climate change. There is a high focus on managing and reducing existing flood risk in the basin through restoring and enhancing natural floodplain capacity and utilising the potential to manage floodwater through new developments, especially within the upstream tributaries.

Great Ouse Catchment Flood Management Plan

2.3.7 To the south and east of the study area some water bodies fall within the Great Ouse CFMP[9] which covers the risk extent from rivers of the Great Ouse basin. The rivers in

[8] Environment Agency (2007), *Thames Region Catchment Flood Management Plan.*
[9] Environment Agency (2011), *Great Ouse Region Catchment Flood Management Plan.*

the study area fall within the Bedford Ouse rural and eastern rivers policy area where Policy 3 is applied i.e. areas of low to moderate flood risk where the Environment Agency are generally managing existing flood risk effectively. The policy enables the LLFA (and Environment Agency, where appropriate) to continue to manage flooding through existing management actions.

West Northamptonshire Water Cycle Study

2.3.8 The West Northamptonshire Water Cycle Study[10] reviews flood risk management options and establishes minimum design standards for new development. It is recommended that flood risk mitigation measures are applied on a strategic basis with impacts elsewhere in the catchment of particular interest. Detailed analysis of the Cherwell catchment is not undertaken, on the basis that there are no significant development areas in the catchment within the West Northamptonshire area.

2.3.9 Surface water management strategies are recommended to apply the 'stormwater management train' which seeks firstly to prevent increased surface water runoff (prevention), secondly to directly infiltrate or recycle (source control), thirdly to collect and control through attenuation or infiltration (site control) and finally to manage combined sites through major attenuation or wetlands (regional control). The water cycle strategy suggests that surface, rather than infiltration based, sustainable drainage systems (SuDS) are likely to be preferable across the region due to generally high groundwater levels in the area.

West Northamptonshire Strategic Flood Risk Assessment

2.3.10 The West Northamptonshire SFRA includes advice on planning policy within the development area and is often used as a basis for policy setting and planning decisions. West Northamptonshire SFRA policy indicates that:

- new development should not increase flood risk;
- surface water should be managed effectively on site; and
- development within flood zones should be safe.

2.3.11 It is specifically recommended that flood risk in the area should be managed by ensuring that development does not increase flood risk either upstream or downstream through increasing surface water runoff or construction which could impede flood water conveyance. Surface water management strategies incorporating SuDS, are recommended for all developments as well as an assessment of the impact on groundwater levels.

West Northamptonshire Joint Core Strategy

2.3.12 The West Northamptonshire Joint Core Strategy is in the final examination stage. Of relevance to flood risk and development are the following objectives:

- Objective 1 – to ensuring development is located and design so as to be resilient to future climate change and risk of flooding;

[10] Halcrow (2011), *West Northamptonshire Water Cycle Study*

- Objective 14 – to protect and enhance existing green infrastructure and biodiversity corridors; and
- Objective 15 – to achieve high quality design that provides a safe, healthy and attractive environment.

2.3.13 Policy C6 sets out the position concerning the Proposed Scheme indicating that the design and construction "must minimise adverse impacts on the environment" and "maximise any benefits that arise from the proposal". Policy BN7 expands on the flood risk management objectives by requiring demonstration "that there is no increased risk of flooding to existing properties" and evidence that developments "seek to improve existing flood risk management". Additionally, the policy states that any proposed surface water management systems should "be accompanied by a long-term management and maintenance plan" and "protect and enhance water quality".

3 Design criteria

3.1.1 It is a requirement of the design that the Proposed Scheme shall be protected against flooding from any source during the 1 in 1,000 years return period (0.1% annual probability) rainfall event with water levels not rising closer than 1m to the top of rail level.

3.1.2 In accordance with the NPPF an allowance for climate change is included in the assessment by assuming that peak rainfall intensity will increase by 30% and that peak river flows will increase by 20%.

4 Data sources

4.1 Primary datasets

4.1.1 Consistent with the requirements of the NPPF this assessment considers the risk of flooding from rivers, direct surface water runoff, rising groundwater, overwhelmed drainage and sewer systems, and artificial sources such as reservoirs, lakes and canals.

4.1.2 The Proposed Scheme lies entirely outside the extent of flooding from the sea and therefore the risk of flooding from tidal sources is not considered in this assessment.

4.1.3 The primary datasets for each source of flooding used to assess the design elements are presented in Table 2. A high-level review of the risk of flooding and potential impacts is undertaken on the basis of these datasets across all flood sources. Where this review indicates potentially significant impacts on the risk of flooding, or a risk of flooding to the route, further investigation in the form of hydraulic modelling is undertaken.

Table 2: Flood risk assessment data sources

Source of flooding	Datasets reviewed	Data owner
Rivers	Flood zone mapping. Detailed River Network. Catchment hydraulic models.	Environment Agency
Surface water	Flood Map for Surface Water (FMfSW). Local surface water flood mapping.	Environment Agency LLFA
Groundwater	Areas susceptible to groundwater flooding. 1:50,000 geological mapping (superficial and bedrock). Potential for elevated groundwater.	British Geological Survey (BGS) LLFA
Drainage and sewer systems	Sewer network plans. Lost river location plans.	Water companies (various) Local planning authority
Artificial sources	Reservoir inundation mapping. Canal infrastructure locations. Trunk water main asset plans.	Environment Agency Canal & River Trust Water companies (various)

4.2 Site familiarisation visits

4.2.1 Site familiarisation visits have been carried out for key locations within the study area where access has been granted. A site familiarisation visit was undertaken in December 2012 to Lower Thorpe to visit the proposed crossing of the Culworth Brook and associated tributary streams and water bodies, where access was granted.

5 The proposed development

5.1 Topography and land use

5.1.1 The land use within the study area is predominantly rural agriculture interspersed with village settlements and isolated farmsteads and dwellings. Ground levels rise from the southern boundary of the area towards the village of Greatworth, which lies approximately 130m east of the Proposed Scheme. Ground levels then fall from Thorpe Mandeville to the floodplain of the River Cherwell, approximately 800m east of the settlement of Edgcote. To the north of the River Cherwell the land rises towards Chipping Warden before descending over a ridge at Aston le Walls into the floodplain of the Highfurlong Brook. North of the Highfurlong Brook the land is flat with higher land towards the east around the villages of Lower and Upper Boddington which lie approximately 450m and 1.2km away from the Proposed Scheme respectively.

5.1.2 This is a predominantly rural area with large areas of open space and woodland, and a small number of recreation grounds in surrounding towns and villages. Calves Close Spinney (woodland) contains derelict buildings some of which are associated with the nearby former Royal Air Force World War II airfield. There is a nature reserve at Glyn Davies Wood managed by Banbury Ornithological Society.

5.2 Local flood risk receptors

5.2.1 The vulnerability of each local receptor with an identified pathway within the study area is presented in Table 3. The vulnerability is classified in accordance with the recommendations of Table 2 in the NPPF Technical Guidance Document and the Scope and Methodology Report (SMR) (see Volume 5: Appendix CT-001-000/1) and the SMR Addendum (see Volume 5: Appendix CT-001-000/2).

Table 3: Vulnerability of local receptors in CFA15

Local receptor	Description	Vulnerability classification	Source/pathway
Greatworth Fields	Residential dwelling and agriculture	More vulnerable	Surface water 200 years - shallow
Greatworth village	Residential dwellings and associated infrastructure including school	More vulnerable	Surface water 30 years - deep
Stuchbury Manor Farm	Residential dwelling and agriculture	More vulnerable	Groundwater - moderate
Home Nurseries	Agriculture/commercial	Less vulnerable	Surface water 200 years - shallow
Keeper's Cottage	Residential dwelling	More vulnerable	Surface water 200 years - shallow
Farm on Magpie Road, Sulgrave	Agriculture	Less vulnerable	Surface water 200 years - shallow
Costow House	Residential dwelling (access track only at risk)	More vulnerable	Surface water 30 years - deep

Local receptor	Description	Vulnerability classification	Source/pathway
Sewage works at Bulls Lane	Sewage treatment works	Less vulnerable	Surface water 30 years - deep
Thorpe Mandeville village	Residential dwellings and associated infrastructure	More vulnerable	Surface water 30 years - shallow
Lower Thorpe hamlet	Residential dwellings	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - deep
Lower Thorpe Farm	Residential dwelling and agriculture	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - deep
Banbury Lane	Infrastructure	Water-compatible	River flooding Flood Zone 3 Surface water 30 years - deep
Wadground Barn	Agriculture	Less vulnerable	Surface water 30 years - deep
Culworth Mill	Residential dwelling	More vulnerable	River flooding Flood Zone 2 Surface water 200 years - shallow Groundwater - high
Mill Lane	Infrastructure	Water-compatible	Surface water 30 years - deep
Keeper's Cottage and Brook House	Residential dwellings	More vulnerable	Surface water 30 years - deep
Edgcote Mill and Home Farm	Residential dwellings and agriculture	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - deep Groundwater - high
Chipping Warden village	Residential dwellings and associated infrastructure including school	More vulnerable	Surface water 30 years - deep
Hall Farm	Residential dwelling and agriculture	More vulnerable	Surface water 30 years - shallow
Bridge Meadow	Agriculture	Less vulnerable	River flooding Flood Zone 3 Boddington Reservoir. Surface water 30 years - deep Groundwater - high
Springfield House	Residential dwelling	More vulnerable	Surface water 30 years - shallow
Road (NN11 6YG)	Infrastructure	Water-compatible	Surface water 200 years - shallow
Cedar House Farm	Residential dwelling and agriculture (access track only at risk)	More vulnerable	Surface water 30 years - shallow
Firtree Nurseries	Agriculture/Commercial	Less vulnerable	Surface water 30 years - shallow

5.3 Description of the Proposed Scheme

5.3.1 The Proposed Scheme through the study area will be approximately 17km in length. Permanent features are shown on Map CT-06-068 to Map CT-06-079 (Volume 2, CFA15 Map Book).

5.3.2 The Proposed Scheme will leave CFA14 on low embankment before passing immediately into cutting up to 10m deep for approximately 2.1km. Three access overbridges will be required along this section together with a 300m noise barrier south of Greatworth and bunding and planting areas along both sides for the length of the cutting.

5.3.3 The following 2.1km of the Proposed Scheme will comprise the Greatworth green tunnel and cutting approaches. The Proposed Scheme will emerge from the Thorpe Mandeville cutting (750m long and 16m deep) cutting to the north of Thorpe Mandeville rising onto embankment at Lower Thorpe and passing through the hamlet on viaduct (7-9m above ground level).

5.3.4 To the north-west of Lower Thorpe the Proposed Scheme will cut up to 26m deep through high land before emerging once again to cross the River Cherwell on viaduct close to Trafford Bridge. At the northern extent of the River Cherwell valley the Proposed Scheme will pass once more into cutting east of Danesmoor Spinney.

5.3.5 The following 2.5km of the Proposed Scheme will comprise the Chipping Warden green tunnel. North of the Chipping Warden tunnel the Proposed Scheme will emerge onto low embankment to approach a viaduct over the Highfurlong Brook. The viaduct will be 150m long.

5.3.6 The final section of the Proposed Scheme within the study area will comprise of an embankment approximately 1.2km long and 5m high, and a cutting approximately 1km long continuing into CFA16 at the northern boundary of the study area. A maintenance loop located west of Claydon Road (also known as Boddington Road).

6 Existing flood risk

6.1 Historical flooding incidents

6.1.1 There are no cases of historic flooding within the study area specifically listed within the publicly available information held by NCC or within the various flood risk documents held by the WNJPU.

6.1.2 Environment Agency records indicate instances of flooding in the River Cherwell north of Edgcote and in the valley of the Highfurlong Brook.

6.2 Risk of flooding from rivers

6.2.1 Within CFA15 the Proposed Scheme will cross the floodplains of the Culworth Brook at Lower Thorpe (SWC-CFA15-02), the River Cherwell north of Edgcote (SWC-CFA15-07), including two minor tributaries (SWC-CFA15-06 and SWC-CFA15-08) and the Highfurlong Brook (SWC-CFA15-09) west of Aston le Walls. All watercourses form part of the River Cherwell catchment.

6.2.2 In addition the Proposed Scheme will cross five minor watercourses which are defined within the Environment Agency river network but do not have associated flood zones. Two of these watercourses are tributaries of the River Cherwell (SWC-CFA15-01 and SWC-CFA15-03) and the remaining three are tributaries of the Highfurlong Brook, including the Boddington Feeder (SWC-CFA15-10, SWC-CFA15-11 and SWC-CFA15-12). These watercourses are assessed within the section that considers the risk of flooding from surface water (Section 6.3 of this report).

Culworth Brook at Lower Thorpe

6.2.3 The watercourses at Lower Thorpe, which combine to form the Culworth Brook, have a catchment size of approximately 3km^2 at the intersection with the Proposed Scheme. The Proposed Scheme will cross a total length of approximately 200m of both Flood Zones 2 and 3, parallel to the natural flow direction. At this location flood zone mapping is only present at the downstream extent of the valley due to the small catchment size. The natural floodplain will extend up the valley and the actual length of floodplain crossed by the route will therefore be greater than the measured lengths of 200m. Hydraulic modelling has been undertaken to define the baseline and assess impacts arising from the Proposed Scheme, and to propose mitigation.

6.2.4 Design elements within the Proposed Scheme that lie within the area at risk of flooding from the watercourses at Lower Thorpe are the Thorpe Mandeville embankment, the Lower Thorpe viaduct and the Lower Thorpe south embankment, as shown on Map CT-06-072 (Volume 2, CFA15 Map Book). Additional elements within the area at risk are the Lower Thorpe maintenance access point where the access road from Banbury Lane will be within the area at risk of flooding.

Hydrology and hydraulic modelling

6.2.5 A hydraulic model has been constructed using InfoWorks ICM v3.0.3. The model utilises the one-dimensional and two-dimensional capabilities of InfoWorks ICM. The

topography of the model is based upon 20cm resolution light detection and ranging (LiDAR) data.

6.2.6 The purpose of the hydraulic model is to confirm the existing hydrology and baseline flood extents of this reach of the Culworth Brook to inform the flood risk assessment.

6.2.7 The main channel of the Culworth Brook was modelled using one-dimensional cross-sections extracted from the LiDAR Digital Terrain Model (DTM). A two-dimensional mesh was used on the right bank of the watercourse where out-of-channel flow was expected. The two-dimensional mesh also included the largest of the fish ponds and the artificial leat that acts as the outfall from the pond that historically would have fed a mill in Lower Thorpe. A more detailed description of the hydrology and the modelling methodology can be found in the Culworth Brook hydraulic modelling report (Volume 5: Appendix WR-004-006).

6.2.8 Inflow hydrographs were constructed using the Revitalised Flood Hydrograph (ReFH) rainfall-runoff methodology for the 20 year, 100 year, 100 year including an allowance for climate change, and 1000 year return period events.

Flood risk to Proposed Scheme

6.2.9 The hydraulic modelling for the Culworth Brook shows that a significant proportion of the flow within the watercourse comes out of the channel upstream of the Thorpe Mandeville embankment and flows overland along the bottom of the valley towards the large pond. The hydraulic modelling results for the Culworth Brook are show on Map WR-05-037 and Map WR-06-037 (Volume 5, Water Resources and Flood Risk Assessment Map Book). Modelled flood depths in this location are up to a maximum of approximately 0.3m for the 1 in 1,000 years return period (0.1% annual probability) flood event. The route will be on embankment as it will cross this section of the valley, with top of rail levels set at approximately 145m above Ordnance Datum (AOD), around 8.7m above surrounding ground levels.

6.2.10 Further to the west the route will be on viaduct as it will cross the watercourse and floodplain. The top of rail level at the Lower Thorpe viaduct is approximately 141.5m AOD, around 9.4m above surrounding ground levels. The depth of overland flow in this location is expected to be shallow (less than 0.3m) and the majority of the flow is predicted to remain within the channel of the Culworth Brook.

6.2.11 As the route is raised throughout the valley of the Culworth Brook on embankment and viaduct there will be no risk of flooding from rivers to the Proposed Scheme in this location.

River Cherwell at Edgcote

6.2.12 The River Cherwell has a catchment size of approximately 80km^2 at the intersection with the Proposed Scheme. The route will cross a total length of approximately 500m and 530m of Flood Zone 3 and 2 respectively with the direction of the route parallel to the natural flow direction.

6.2.13 No hydraulic model of the River Cherwell is held by the Environment Agency that covers this location.

6.2.14 Design elements within the Proposed Scheme that lie within the area at risk of flooding from the River Cherwell and the two tributaries at this location are the Edgcote south embankment, the Edgcote viaduct and the Edgcote north embankment. The access track from Welsh Road to the balancing pond north of the Edgcote viaduct also lies within the area at risk.

Hydrology and hydraulic modelling

6.2.15 The design includes hydraulic modelling of the River Cherwell at this crossing. The conceptual model indicates flood water levels of 109.3m AOD at the downstream extent and 109.9m AOD at the upstream extent during the 1 in 100 years return period (1% annual probability) flood event. Corresponding flood water levels in the 1 in 1,000 years return period (0.1% annual probability) event are 109.7m AOD and 110.1m AOD respectively.

Flood risk to Proposed Scheme

6.2.16 The hydraulic modelling results for the River Cherwell are show on Map WR-05-038 and Map WR-06-038 (Volume 5, Water Resources and Flood Risk Assessment Map Book). The route will be on viaduct for the crossing of the River Cherwell and its floodplain. The top of rail level across the viaduct varies slightly from 118m AOD at its southern extent, 117m AOD at the crossing of the River Cherwell, to 116.5m AOD at its northern extent. The maximum flood water level beneath the Proposed Scheme where it will cross the channel of the River Cherwell for the 1 in 1,000 years return period (0.1% annual probability) flood event is approximately 110.4m AOD. Therefore there will be a 6.6m freeboard between the maximum 1 in 1,000 years return period (0.1% annual probability) flood water level and the top of rail level of the Proposed Scheme.

6.2.17 The Proposed Scheme will not be at risk of flooding from the River Cherwell.

Highfurlong Brook

6.2.18 The Highfurlong Brook has a catchment size of approximately 25km^2 at the intersection with the Proposed Scheme. The route will cross a total length of approximately 170m and 190m of Flood Zone 3 and 2 respectively perpendicular to the natural flow direction.

6.2.19 Design elements that lie within the area at risk of flooding from the Highfurlong Brook are the Aston le Walls embankment, the Highfurlong Brook viaduct and the Highfurlong Brook embankment.

Hydrology and hydraulic modelling

6.2.20 No hydraulic model of the Highfurlong Brook is held by the Environment Agency that covers this location. The design, however, includes conceptual hydraulic modelling of at this crossing. A more detailed description of the hydrology and the modelling methodology can be found in Highfurlong Brook hydraulic modelling report (Volume 5: Appendix WR-004-008). The hydraulic modelling results for the Highfurlong Brook are show on Map WR-05-040 and Map WR-06-040 (Volume 5, Water Resources and Flood Risk Assessment Map Book).

6.2.21 The baseline estimates of maximum flood water levels at the crossing are presented in Table 4. The minimum top of rail level within the area of flood risk will be at the northern extent, on Highfurlong Brook embankment, and will be 115.1m AOD. There will therefore be a freeboard of 7.6m between the 1 in 1,000 years return period (0.1% annual probability) flood water level and the minimum top of rail level.

Table 4: Highfurlong Brook model details

	100 years return period	100 years return period including climate change	1,000 years return period
Peak flow	15.1m^3/s	18.2m^3/s	26.3m^3/s
Baseline flood level	107.41m AOD	107.45m AOD	107.54m AOD

Flood risk to Proposed Scheme

6.2.22 Comparison of the Proposed Scheme with the predicted flood water levels from the conceptual hydraulic modelling shows that the minimum top of rail level will be at least 7.6m above the predicted 1 in 1,000 years return period (0.1% annual probability) flood water level. As a result the risk of flooding to the route will be less than 0.1% (low risk). There are no other elements of the Proposed Scheme at this location that will potentially be at risk of flooding.

6.3 Risk of flooding from surface water

Radstone

6.3.1 At the southern extent of the study area the Proposed Scheme will cross a dry valley. The FMfSW shows 'deep' (greater than 300mm depth) surface water flooding in the 1 in 30 years return period (3.3% annual probability) rainfall event at the watercourse crossing and 'shallow' (greater than 100mm deep but less than 300mm deep) flooding in the 1 in 30 years return period (3.3% annual probability) rainfall event at the northern dry valley. Design elements that lie within the area at risk of flooding are Greatworth south embankment, Greatworth south cutting and Footpath AN22 accommodation overbridge.

6.3.2 The Proposed Scheme will be on a low embankment at the watercourse crossing (Greatworth south embankment). The surrounding ground level is approximately 148m AOD. The top of rail level at the watercourse crossing will be 150.5m AOD, more than 2m above ground levels. Comparison of the FMfSW outlines with ground levels suggests a 1 in 200 years return period (0.5% annual probability) flood level of no more than 148m AOD. There will therefore be a freeboard of at least 2m between the 1 in 200 years return period (0.5% annual probability) flood water level and the minimum top of rail level at the watercourse crossing (no risk).

6.3.3 Where the Proposed Scheme will cross the dry valley the vertical alignment is close to ground level approaching the Greatworth south cutting. As such, there will be a risk of flooding arising to the Proposed Scheme from overland surface water flow within this valley. Surface water flow in the dry valley on both sides of the Proposed Scheme will

be collected and diverted southwards alongside the route to the watercourse which will be conveyed beneath the Proposed Scheme in a 1,350mm diameter culvert.

6.3.4 The public right of way (PRoW) overbridge will be raised on embankment to pass over the Proposed Scheme and will be several metres above ground level where it will cross the area of flood risk.

6.3.5 There will be no significant risk of flooding to the Proposed Scheme (including the Greatworth south embankment and Footpath AN22 accommodation overbridge) at the Radstone Brook tributary.

Greatworth Fields

6.3.6 To the east of Greatworth Fields the Proposed Scheme will cross a dry valley. The FMfSW shows the base of the valley, to a distance of approximately 40m upstream of the Proposed Scheme, to be at risk of 'shallow' flooding in the 1 in 200 years return period (0.5% annual probability) rainfall event. There will be one design element within the area at risk of flooding - the Greatworth south cutting.

6.3.7 The Proposed Scheme will be in a shallow cutting at this location approximately 2.6m deep. The design allows for a drop inlet culvert of 1350mm diameter and 245m in length that is designed to convey the calculated 1 in 100 years return period (1% annual probability) flow including an allowance for climate change of 0.62m^3/s. The design avoids the need for an inverted siphon.

Greatworth Hall

6.3.8 To the east of Greatworth the Proposed Scheme will cross a dry valley. The FMfSW shows the base of the valley, to a distance of approximately 60m upstream of the Proposed Scheme, to be at risk of 'shallow' flooding in the 1 in 200 years return period (0.5% annual probability) rainfall event. There will be one design element within the area at risk of flooding - the Greatworth North embankment.

6.3.9 The Proposed Scheme will be on a low embankment at the dry valley crossing. The ground level is approximately 153m AOD. The top of rail level at the watercourse crossing will be 158.1m AOD, more than 5m above ground levels. Comparison of the 100mm FMfSW outlines with ground levels suggests a 1 in 200 years return period (0.5% annual probability) flood level of no more than 153.3m AOD. There will therefore be a freeboard of at least 4.8m between the 1 in 200 years return period (0.5% annual probability) flood water level and the minimum top of rail level at the watercourse crossing. There will be no risk of flooding to the Proposed Scheme at the Greatworth Hall dry valley.

Painter's Spinney

6.3.10 West of Painter's Spinney the Proposed Scheme will cross a dry valley within land currently belonging to the Marston St Lawrence Estate. The FMfSW shows the base of the valley, to a distance of approximately 40m upstream of the Proposed Scheme, to be at risk of 'shallow' flooding in the 1 in 200 years return period (0.5% annual probability) rainfall event. The Proposed Scheme will be within green tunnel through the area of risk and is therefore not considered to be at risk of flooding from this source.

Costow Farm

6.3.11 East of Costow House the Proposed Scheme will cross a dry valley and source of a small stream within land currently belonging to Costow Farm. The FMfSW shows the base of the valley to be at risk of 'shallow' flooding in the 1 in 30 years return period (3.3% annual probability) rainfall event and 'deep' flooding in the 1 in 200 years return period (0.5% annual probability) rainfall event. There is a risk of surface water flooding shown to a distance of approximately 550m upstream of the Proposed Scheme. There will be one design element within the area at risk of flooding - the Thorpe Mandeville cutting.

6.3.12 The Proposed Scheme will be in deep cutting at the valley crossing, at the north portal of the Greatworth green tunnel. The ground level is approximately 155m AOD. The top of rail level at the watercourse crossing will be 149.6m AOD, more than 5m below current ground levels. Comparison of the FMfSW outlines with ground levels suggests a 1 in 200 years return period (0.5% annual probability) flood level of no more than 153.3m AOD. There will therefore be a significant risk of flooding to the Proposed Scheme.

6.3.13 The Proposed Scheme will include the creation of a diverted runoff pathway along the east side of the route discharging to the ponds at Lower Thorpe. The catchment size at Costow House, downstream of the Proposed Scheme, is 0.5km^2, with a corresponding 1 in 100 years return period (1% annual probability) peak flood flow (including a 30% allowance for climate change) of 0.8m^3/s.

Lower Thorpe

6.3.14 From north-east of Thorpe Mandeville to Lower Thorpe the Proposed Scheme will cross an area shown on the FMfSW to be at risk of 'deep' surface water flooding in the 1 in 30 years return period (3.3% annual probability) rainfall event. When reviewing this dataset it was noted that the extent of flooding upstream of the crossing of the Thorpe Mandeville embankment did not follow the bottom of the valley and therefore hydraulic modelling was undertaken. The hydraulic modelling results are show on Map WR-05-037 and Map WR-06-037 (Volume 5, Water Resources and Flood Risk Assessment Map Book). The flood risk to the Proposed Scheme and impact of the Proposed Scheme on flood risk elsewhere are considered in the river flooding parts of Section 6 and Section 8 respectively of this report.

Banbury branch line

6.3.15 Approximately 500m north-west of Lower Thorpe the Proposed Scheme will cross a small stream within land currently belonging to Culworth Grounds Farm. The FMfSW indicates a risk of 'deep' flooding in the 1 in 30 years return period (3.3% annual probability) rainfall event along the base of the valley. There will be one design element within the area at risk of flooding - the Lower Thorpe North embankment.

6.3.16 The Proposed Scheme will be on embankment across the valley. The stream will be diverted along the west side of the Proposed Scheme before being conveyed beneath the embankment in a 1350mm diameter culvert.

6.3.17 The ground level profiles suggest that the ground level at the crossing is approximately 130m AOD. The top of rail level at the watercourse crossing will be 137m AOD, 7m above ground levels. Comparison of the FMfSW outlines with ground levels suggests a 1 in 200 years return period (0.5% annual probability) flood level of no more than 131m AOD. There will therefore be a freeboard of at least 6m between the 1 in 200 years return period (0.5% annual probability) flood water level and the minimum top of rail level at the watercourse crossing. There will be no significant risk of flooding to the Proposed Scheme at the Banbury branch line.

Danes Moor public bridleway

6.3.18 To the east of Danes Moor the Proposed Scheme will cross the route of a public bridleway. The southern approach embankment for the proposed overbridge will cross a dry valley. The FMfSW shows the base of the valley to be at risk of 'shallow' flooding in both the 1 in 30 years and 1 in 200 years return period (3.3% and 0.5% annual probability) rainfall events.

6.3.19 At the base of the dry valley the bridleway is returning to ground level. As a result there is a potential risk of flooding to the bridleway itself from surface water sources. The Proposed Scheme, however, will result in a minor improvement to the risk of flooding from this source firstly due to proposed collection of surface water into a culvert beneath the embankment thus reducing the extent of direct surface water runoff and ponding, and secondly by raising the bridleway above existing levels.

River Cherwell

6.3.20 The FMfSW indicates areas of 'deep' flooding along the valley of the River Cherwell in the 1 in 30 years return period (3.3% annual probability) rainfall event prior to surface water runoff reaching the channel. The extent of flooding is within the flood zone extents for the watercourse and, since flooding from direct surface water runoff occurs early in any given rainfall event, are likely to have receded prior to the onset of any significant flooding from the watercourse. On this basis there is unlikely to be any significant cumulative effect due to combined flooding from surface water runoff and from the watercourse that is not accounted for in the analysis of the River Cherwell. As a result the flood risk considered in Section 6.2 will be the dominant source of risk to the Proposed Scheme, with additional surface water risks likely to be negligible.

Highfurlong Brook

6.3.21 The FMfSW indicates areas of 'deep' flooding along the valley of the Highfurlong Brook in the 1 in 30 years return period (3.3% annual probability) rainfall event prior to surface water runoff reaching the channel. The extent of flooding is within the flood zone extents for the watercourse and, since flooding from direct surface water runoff occurs early in any given rainfall event, are likely to have receded prior to the onset of any significant flooding from the watercourse. On this basis there is unlikely to be any significant cumulative effect due to combined flooding from surface water runoff and from the watercourse that is not accounted for in the analysis of the Highfurlong Brook. As a result the flood risk considered in Section 6.2 will be the dominant source of risk to the Proposed Scheme, with additional surface water risks likely to be negligible.

Hill Road

6.3.22 To the south of Lower Boddington the Proposed Scheme will cross a dry valley which lies along the western edge of Hill Road. There is a watercourse that runs along the eastern edge of Hill Road which collects surface water runoff from the east, however the dry valley receives all runoff from the slopes to the west of Hill Road. The FMfSW indicates a risk of 'shallow' surface water flooding in both the 1 in 30 years and 1 in 200 years return period (3.3% and 0.5% annual probability) rainfall events within this dry valley which connects with another dry valley from the west around 400m downstream of the potential crossing. Both valleys continue south producing the Springfield Brook a further 1km downstream. The Proposed Scheme will incorporate a new overbridge for Hill Road with raised earth approach embankments. Design elements that lie within the area at risk of flooding are the Lower Boddington cutting and Claydon Road overbridge.

6.3.23 The existing stream on the east side of the road will be diverted along the foot of the Hill Road approach embankments and conveyed beneath the Proposed Scheme in an inverted siphon. There are no FMfSW extents associated with the stream.

6.3.24 The Proposed Scheme will be in a shallow cutting approximately 1m deep at the crossing of the dry valley. The route, however, will be surrounded at this location by raised noise barriers which will prevent the overland progression of floodwaters through the dry valley. Surface water will be collected in a land drainage system constructed as part of the Proposed Scheme and discharged north to the Boddington canal feeder.

Cedar House Farm

6.3.25 Approximately 650m west of Lower Boddington, between Cedar House Farm and Fir Tree House, the Proposed Scheme will cross a dry valley within land currently belonging to Cedar House Farm. The FMfSW shows a risk of 'shallow' surface water flooding in both the 1 in 30 years and 1 in 200 years return period (3.3% and 0.5% annual probability) rainfall events. The dry valley at this location is particularly well defined and ultimately forms the Springfield Brook, a tributary of the Wormleigh Brook, approximately 1.6km downstream of the Proposed Scheme. The principal design element that lies within the area at risk of flooding is the Lower Boddington embankment.

6.3.26 The Proposed Scheme will be on embankment across the valley. The ground profiles suggest that the ground level is around 113m AOD. The top of rail level at the watercourse crossing will be a minimum of 115.3m AOD, more than 2m above ground levels. Comparison of the FMfSW outlines with ground levels suggests a 1 in 200 years return period (0.5% annual probability) flood level of no more than 113.3m AOD. There will therefore be a freeboard of at least 2.0m between the 1 in 200 years return period (0.5% annual probability) flood water level and the minimum top of rail level at the watercourse crossing. There will be no significant risk of flooding to the Proposed Scheme at the Cedar House Farm dry valley.

6.4 Risk of flooding from groundwater

6.4.1 The BGS dataset indicates that the Proposed Scheme will intersect areas of 'high' and 'very high' susceptibility to flooding from groundwater within the local superficial deposits near Halse Copse, along the Cherwell Valley near Edgcote and along the Highfurlong Brook valley.

6.4.2 For there to be a risk of flooding from groundwater the relevant receptor needs to be below ground or at the surface. Consequently, where the Proposed Scheme is raised above surrounding ground, either on embankment or viaduct, the risk of flooding from groundwater is negligible. The Cherwell and Highfurlong Brook areas will be crossed on viaduct, however the route will be at grade through the area at risk near Halse Copse.

Halse Copse

6.4.3 The BGS susceptibility to groundwater flooding maps show an area at risk of groundwater emergence arising from superficial deposits along the watercourse and dry valley identified above as being at risk of surface water flooding. The BGS dataset describes the superficial strata as unproductive glacial till (Diamicton). The bedrock is the Rutland Formation which comprises mudstone and siltstone.

6.4.4 The area susceptible to groundwater flooding coincides with the area at risk of surface water flooding along the dry valley. Groundwater that emerges onto the surface will follow natural drainage pathways and therefore be intercepted by the proposed collection systems described in Section 6.3 of this report. Since the Proposed Scheme will be at the surface in the area of susceptibility there will be no increased risk to the Proposed Scheme from sub-surface groundwater.

6.5 Risk of flooding from drainage systems

6.5.1 With the exception of Lower Thorpe, the Proposed Scheme will not pass through any urban areas for the full extent within the study area. At Lower Thorpe the Proposed Scheme will be a minimum of 6.8m above surrounding ground levels. There will consequently be no significant risk to the Proposed Scheme of flooding from drainage systems within the Greatworth to Lower Boddington area.

6.6 Risk of flooding from artificial sources

Boddington reservoir

6.6.1 At the crossing of the Highfurlong Brook the Proposed Scheme also intersects an area shown to be at risk on the Environment Agency reservoir flood maps in the event of failure of the Boddington Reservoir. The modelled extent shows the largest area that might be flooded if the reservoir were to fail and fully release all of the water that it holds, which is shown to be greater than the extent of the flood zones of the Highfurlong Brook. Design elements that lie within the area at risk of flooding are the Aston le Walls embankment, Highfurlong Brook viaduct and Highfurlong Brook embankment.

6.6.2 The Environment Agency's online mapping only displays the residual risk of failure of artificial water bodies with a capacity above 25,000m^3 which are covered by the Reservoirs Act 1975[11], as amended by the Flood and Water Management Act 2009[12]. This requires water companies to maintain their reservoirs such that the annual probability of a breach of the reservoir is 1 in 50,000. Although there is a potential impact from the Proposed Scheme on the risk of flooding from the reservoir the likelihood of such flooding occurring is extremely low.

6.6.3 Comparison of the reservoir inundation map with LiDAR ground level information suggests a maximum flood level of 111m AOD since the outlines lie within the 111m AOD contour. The minimum top of rail level at the crossing will be 114.1m AOD and there will therefore be a freeboard of over 3m above the predicted maximum water level. In the event of a reservoir breach flood flows will be expected to be rapid.

6.6.4 There will not be a significant risk of flooding to the Proposed Scheme from failure of the Boddington Reservoir.

6.7 Summary of baseline flood risk

Table 5: Summary of baseline flood risk for all sources of flooding in CFA15

Source of flooding	Location of flooding source	Flood risk category	Elements at risk	Assessment of risk
River	Culworth Brook	Very High Flood Zone 3b	Thorpe Mandeville embankment	Top of rail level will be >1m above 1,000 years return period water level.
			Lower Thorpe viaduct	
			Lower Thorpe embankment	
			Lower Thorpe maintenance access point	
River	River Cherwell	High Flood Zone 3a	Edgcote south embankment	Top of rail level will be >1m above 1,000 years return period water level.
		Very high Flood Zone 3b	Edgcote viaduct	
			Edgcote north embankment	
River	Highfurlong Brook	High Flood Zone 3a	Aston le Walls embankment	Top of rail level will be >1m above 1,000 years return period water level.
		Very high Flood Zone 3b	Highfurlong Brook viaduct	
		High Flood Zone 3a	Highfurlong Brook embankment	
Surface water	Radstone	Medium Surface water	Greatworth south embankment	Top of rail level and footpath level will be >1m above

[11] *Reservoirs Act 1975* (c.23). London, Her Majesty's Stationery Office.
[12] *Flood and Water Management Act 2010* (c.29). London, Her Majesty's Stationery Office.

Source of flooding	Location of flooding source	Flood risk category	Elements at risk	Assessment of risk
		200 years - deep Surface water 30 years - shallow	Greatworth south cutting	estimated flood water level.
			Footpath AN22 accommodation overbridge	
Surface water	Greatworth Fields	Low Surface water 200 years - shallow	Greatworth south cutting	Top of rail level will be in cutting below adjacent ground level. Land drainage will convey surface water runoff beneath the Proposed Scheme in a drop-inlet culvert.
Surface water	Greatworth Hall	Low Surface water 200 years - shallow	Greatworth north embankment	Top of rail level will be >1m above estimated flood water level.
Surface water	Painter's Spinney	Low Surface water 200 years- shallow	Greatworth green tunnel	Proposed Scheme will be in tunnel.
Surface water	Costow Farm	Medium Surface water 200 years - deep Surface water 30 years - shallow	Thorpe Mandeville cutting	Top of rail level will be in cutting below adjacent ground level. Land drainage will convey surface water runoff to the ponds at Lower Thorpe.
Surface water	Lower Thorpe	High Surface water 30 years - deep	Thorpe Mandeville embankment	Top of rail level will be >1m above estimated flood water level. See risk of flooding from rivers.
			Lower Thorpe viaduct	
			Lower Thorpe embankment	
			Lower Thorpe maintenance access point	See risk of flooding from rivers.
Surface water	Banbury branch line	High Surface water 30 years - deep	Lower Thorpe north embankment	Top of rail level will be >1m above estimated flood water level.
Surface water	Danes Moor public bridleway	Medium Surface water 200 years - shallow Surface water 30 years - shallow	Bridleway AG9 overbridge	Level of bridleway will be raised relative to existing alignment.

Source of flooding	Location of flooding source	Flood risk category	Elements at risk	Assessment of risk
Surface water	Hill Road	Medium Surface water 200 years FMfSW <0.3m Surface water 30 years - shallow	Lower Boddington cutting	Top of rail level will be in cutting below adjacent ground level. Land drainage will convey surface water runoff to the Boddington feeder.
			Claydon Road overbridge	Road level will be >1m above surrounding ground.
Surface water	Cedar House Farm	Medium Surface water 200 years- shallow Surface water 30 years - shallow	Lower Boddington embankment	Top of rail level will be >1m above estimated flood water level.
Groundwater	Halse Copse	High Groundwater - very high susceptibility	Greatworth south cutting	Groundwater will be collected into surface water drainage system and discharged to local watercourses.
Artificial sources	Boddington reservoir	Low Within inundation mapping extent	Aston le Walls embankment	Top of rail level will be >1m above estimated flood water level.
			Highfurlong Brook viaduct	
			Highfurlong Brook embankment	

7 Flood risk management measures

7.1 Risk of flooding from rivers

7.1.1 The Proposed Scheme will be raised above crossings of floodplains (river flooding) such that the risk of flooding from this source is less than 0.1%. Therefore there are no instances where the Proposed Scheme will be at significant risk of river flooding and consequently no specific mitigation is required.

7.1.2 At all flood zone crossings replacement floodplain storage will be provided upstream of the Proposed Scheme, or adjacent to the area removed, for all losses in floodplain storage including embankments and all associated development. This applies to the Lower Thorpe, River Cherwell including its tributaries and the Highfurlong Brook crossings. Specific mitigation for hydrodynamic effects is detailed below.

Lower Thorpe

7.1.3 Land has been made available for replacement floodplain storage upstream of the culvert through the Thorpe Mandeville embankment to mitigate for any loss in flood storage. Additional replacement storage will be provided to the east of the large pond due to loss of storage within the pond and due to the piers of the Lower Thorpe viaduct. It is not considered necessary to provide any additional specific mitigation at the Culworth Brook.

Edgcote

7.1.4 Replacement floodplain storage will be provided to mitigate for any loss of flood storage as a result of the viaduct piers crossing the floodplain of the River Cherwell. The River Cherwell will be diverted in two locations where the viaduct piers have been sited close to the watercourse. The diversions will maintain conveyance within the channel. It is not considered necessary to provide any additional specific mitigation at the River Cherwell.

Highfurlong Brook

7.1.5 Conceptual modelling of the Highfurlong Brook suggests that the Proposed Scheme will result in an afflux of up to 20mm, extending to a maximum distance of 150m upstream of the Highfurlong Brook viaduct. Replacement floodplain storage will be provided upstream of the crossing.

7.2 Risk of flooding from surface water

7.2.1 The FMfSW shows the extent of flooding due to rainfall that would occur prior to collection of water into streams or designated drainage infrastructure. By collecting the flows from the dry valley into an adequately designed land drainage system the Proposed Scheme will effectively remove the risk of surface water flooding from the point at which the flow is intercepted.

7.2.2 Measures to manage the risk of flooding from surface water runoff include;

- provision of replacement storage and surface water attenuation facilities to restrict peak surface water runoff rates to existing rates;

- culverts have been designed with adequate capacity to convey the 1 in 100 years (1% annual probability) flow including an allowance for climate change; and
- design of culverts with internal 600mm freeboard and 300mm allowance for siltation to minimise the chances of blockage or future capacity restrictions

7.2.3 There are four locations where the top of rail level of the Proposed Scheme will be less than 1m above ground level in an area shown to be at risk of flooding from direct surface water runoff. At Radstone and Greatworth Fields surface water will be collected into drainage systems and discharged within existing watercourses beneath the Proposed Scheme in culverts. At the Thorpe Mandeville cutting the Proposed Scheme will be in deep cut through the dry valley. Flows will be intercepted some distance upstream of the Proposed Scheme and discharged along a newly created watercourse to the east of the route, to the ponds at Lower Thorpe.

7.2.4 North of Hill Road surface water on the upstream side of the Proposed Scheme will be redirected northwards to the Boddington canal feeder by the noise barriers. Due to the redirection of surface water runoff on the east side of the Proposed Scheme west of Lower Boddington there will be potential changes in discharges to the Boddington canal feeder. Surface water will be attenuated prior to discharge at greenfield rates subject to the approval of the LLFA in order to prevent exceeding the capacity of the canal feeder.

7.3 Risk of flooding from groundwater

7.3.1 There is a risk of flooding arising from an area of 'High' susceptibility to groundwater emergence south of Halse Copse. This area coincides with an existing natural valley and watercourse. Surface water will be collected into drainage systems and discharged within existing watercourses beneath the Proposed Scheme in a culvert. It is likely that any groundwater flooding will follow the same flow pathways as surface water flooding and likewise be intercepted by the surface water drainage systems. The Proposed Scheme will be in shallow cutting through the area at risk. Groundwater will be collected at the base of the cutting to prevent flooding of the Proposed Scheme.

7.3.2 There will not be any significant impact on the risk of flooding from groundwater arising from the Proposed Scheme and therefore no specific mitigation will be required.

7.4 Risk of flooding from drainage systems

7.4.1 There will be no risk of flooding from drainage systems to the Proposed Scheme nor any anticipated effects on the risks of flooding from drainage systems within the study area arising from the Proposed Scheme. Therefore, no specific mitigation will be required.

7.5 Risk of flooding from artificial sources

7.5.1 There are no instances where the Proposed Scheme will be at significant risk of flooding from artificial sources nor any anticipated effects on the risks of flooding from artificial sources within the study area arising from the Proposed Scheme. Therefore, no specific mitigation will be required.

7.5.2 Although the potential flood water level resulting from complete failure of the Boddington Reservoir would be up to 3m higher than the predicted water levels in the Highfurlong Brook, the replacement floodplain storage provided to mitigate potential effects on the risk of flooding from rivers will serve to partially offset any potential effects due to the severe flooding from this source. Due to the extremely low probability of such flooding occurring, and the likely low significance of any impacts arising from the Proposed Scheme, it is not considered practical to provide additional mitigation for this scenario.

8 Post-development flood risk assessment

8.1 Local receptors

8.1.1 In addition to the risk of flooding that exists to the Proposed Scheme, there is potential for the Proposed Scheme to affect the risk of flooding to third party receptors by altering flow mechanics across the range of flood sources. All local receptors with a potential flood risk are identified in Section 5.2 of this report. For the Proposed Scheme to have an impact on a given receptor the identified pathway for that receptor must be shared by both the subject receptor and the Proposed Scheme with the result that a number of cases can be excluded immediately. Table 6 summarises the shared pathways between the Proposed Scheme and each receptor and identifies cases where no shared pathway exists.

Table 6: Shared flood risk pathways in CFA15

Local receptor	Vulnerability classification as per the NPPF	Pathway	Shared pathway between Proposed Scheme and receptor
Greatworth Fields	More vulnerable	Surface water 200 years - shallow	No shared pathway.
Greatworth village	More vulnerable	Surface water 30 years - deep	No shared pathway.
Stuchbury Manor Farm	More vulnerable	Groundwater - moderate	No shared pathway.
Home Nurseries	Less vulnerable	Surface water 200 years - shallow	No shared pathway.
Keeper's Cottage	More vulnerable	Surface water 200 years - shallow	No shared pathway.
Farm on Magpie Road, Sulgrave	Less vulnerable	Surface water 200 years - shallow	No shared pathway.
Costow House (access track)	More vulnerable	Surface water 30 years - deep	Greatworth tunnel north portal will be approximately 400m upstream. Thorpe Mandeville embankment will be approximately 500m downstream.
Sewage works at Bulls Lane	Less vulnerable	Surface water 30 years - deep	Greatworth green tunnel north portal will be approximately 600m upstream. Thorpe Mandeville embankment will be approximately 300m downstream
Thorpe Mandeville village	More vulnerable	Surface water 30 years - shallow	Thorpe Mandeville embankment will be approximately 900m downstream

Local receptor	Vulnerability classification as per the NPPF	Pathway	Shared pathway between Proposed Scheme and receptor
Lower Thorpe hamlet	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - deep	Thorpe Mandeville and Lower Thorpe embankments; Lower Thorpe viaduct and Banbury Lane maintenance access point will be at this location
Lower Thorpe Farm	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - deep	Thorpe Mandeville and Lower Thorpe embankments; Lower Thorpe viaduct and Banbury Lane maintenance access point will be immediately upstream.
Wadground Barn	Less vulnerable	Surface water 30 years - deep	Edgcote viaduct will be approximately 1.3km downstream
Culworth Mill	More vulnerable	River flooding Flood Zone 2 Surface water 200 years - shallow Groundwater - high	Edgcote viaduct will be approximately 300m downstream
Mill Lane	Water compatible	Surface water 30 years - deep	Edgcote viaduct will be at this location
Keeper's Cottage and Brook House	More vulnerable	Surface water 30 years - deep	No shared pathway.
Edgcote Mill and Home Farm	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - deep Groundwater - high	Edgcote viaduct will be approximately 1.0km upstream
Chipping Warden village	More vulnerable	Surface water 30 years - deep	No shared pathway.
Hall Farm	More vulnerable	Surface water 30 years - shallow	No shared pathway.
Bridge Meadow	Less vulnerable	River flooding Flood Zone 3 Surface water 30 years - deep Boddington Reservoir Groundwater - high	Highfurlong Brook viaduct will be approximately 1.0km downstream
Springfield House	More vulnerable	Surface water 30 years - shallow	Lower Boddington cutting and embankment will be approximately 800m and 1.0km upstream
Cedar House Farm (access track)	More vulnerable	Surface water 30 years - shallow	Lower Boddington cutting and embankment will be approximately 100m downstream
Firtree Nurseries	Less vulnerable	Surface water 30 years - shallow	Lower Boddington cutting and embankment will be at this location

8.1.2 There is also the potential for the Proposed Scheme to change the baseline risk of flooding described in the Section 6 of this report. Though designed such that the probability of the Proposed Scheme flooding in any given year is less than 1 in 1,000, any change to the baseline risk of flooding could impact on the assessment of flood risk to the Proposed Scheme. All cases of flood risk discussed in Section 6 of this report are therefore reconsidered regardless of the presence or otherwise of third party local receptors.

8.2 Impact on risk of flooding from rivers

Lower Thorpe

Description

8.2.1 The Proposed Scheme will cross the Culworth Brook, a tributary of the River Cherwell, at Lower Thorpe. A more detailed description of the hydraulic connectivity of these lakes can be found in the Culworth Brook hydraulic modelling report (Volume 5: Appendix WR-004-006). The Culworth Brook is flowing in a northerly direction upstream of the Thorpe Mandeville embankment where the watercourse has been artificially modified and straightened to the west of its original alignment for the construction of a series of boating and wildfowl breeding ponds. There is believed to be hydraulic connectivity between the main channel of the Culworth Brook and the largest of the three ponds at its south-western corner.

8.2.2 The stream then flows parallel to the Proposed Scheme for approximately 500m before turning north. The crossing is towards the head of the catchment. Environment Agency flood zone mapping begins approximately halfway between the initial intersection of the route and Banbury Lane, where the stream turns north. Environment Agency mapping typically begins at a catchment size of 3km^2. Lower Thorpe is at a confluence between the Culworth Brook and two of its tributaries. The Culworth Brook is culverted through the hamlet beneath Banbury Lane.

8.2.3 Along the valley of the tributary from the direction of Magpie Farm there is a series of three ponds which appear to be online to the tributary watercourse. The outfall from the large ponds is to an artificial leat[13] that was believed to have been constructed to supply water to a mill in Lower Thorpe. The leat is raised above the natural floodplain and out-of-bank flood flows from the lake and stream channel have been shown to flow south to the main channel of the Culworth Brook at the natural valley bottom, crossing the centre line of the Proposed Scheme from east to west. The leat is believed to be hydraulically connected to the main channel of the Culworth Brook via a series of ponds prior to the watercourse entering the culvert beneath Banbury Lane.

Local receptors and land use

8.2.4 Formal receptors within the study area that could be affected by the Proposed Scheme around Lower Thorpe are Lower Thorpe hamlet (including Twin Oaks, Water End and Manor Cottages) and Lower Thorpe Farm. Partial demolition will be undertaken at Lower Thorpe Farm to enable construction of the Proposed Scheme.

[13] A leat is a local reference to a small watercourse that was artificially created to transfer water, predominantly to a mill.

8.2.5 The land use in the floodplain around the Proposed Scheme location is largely made up of arable farm land and pasture, with the exception of the hamlet itself. There is an ancient monument to the north-east and two ponds beneath the line of the proposed viaduct. These ponds do not appear on historical mapping prior to 1955 and are therefore likely to be ornamental without any specific hydrological function.

Potential effects

8.2.6 There are three key design elements that have the potential to affect flood flows at Lower Thorpe. These are the Thorpe Mandeville and Lower Thorpe embankments and the Lower Thorpe viaduct. The main channel of the Culworth Brook and the largest of the ponds will be affected by the Proposed Scheme.

8.2.7 The earthworks for the Thorpe Mandeville embankment will cross the line of the Culworth Brook for approximately 80m. The Culworth Brook will be culverted beneath the Thorpe Mandeville embankment with downstream flows diverted into the large pond. This will have an effect on the hydraulic characteristics of the channel and will alter flooding regimes. The eastern side of the embankment will displace a significant volume of the pond. The pond is online to the northern channel and therefore flood storage volume will be removed by filling in a proportion of the lake.

8.2.8 In addition the out-of-bank flooding interaction of the lake and leat with the main channel of the Culworth Brook will be obstructed, potentially leading to flooding on the eastern side of the embankment.

8.2.9 The Lower Thorpe viaduct will be 190m in length with piers at approximately 20m centres. The southern channel is culverted beneath Banbury Lane at the point of crossing and consequently there will be no viaduct piers in the channel. The northern channel lies beneath the footprint of the proposed viaduct for approximately 40m. The Proposed Scheme, however, will not place any piers within the channel. Viaduct piers within the floodplain will potentially obstruct flood flows leading to increases in flood water levels in the area, particularly when the cumulative impact of each pier is considered, since the viaduct passes along the valley bottom parallel to the direction of flood flow. Each viaduct pier will additionally displace flood water, leading to further potential increases in surrounding flood water levels.

8.2.10 The Lower Thorpe embankment (northern abutment) footprint will encroach into the floodplain on the eastern side of the structure. Approximately 400m^2 of floodplain in plan area will be displaced leading to a potential increase in flood risk elsewhere in the vicinity.

8.2.11 An access road is proposed from Banbury Lane to the Lower Thorpe maintenance access point and radio mast, as well as balancing ponds nearby. This access road will cross the channel of the watercourse, together with approximately 70% of the width of the floodplain, perpendicular to the flow, around 60m downstream of the Lower Thorpe viaduct. The length of road within Flood Zone 2 will be approximately 40m. The access road will be on embankment across the floodplain, with the stream conveyed within a short (approximately 8m) culvert, although no design details are available at this stage.

Assessment of effects

8.2.12 The hydraulic modelling results for the Culworth Brook are show on Map WR-05-037 and Map WR-06-037 (Volume 5, Water Resources and Flood Risk Assessment Map Book). The hydraulic modelling determined that the primary flowpath upstream of the Thorpe Mandeville embankment is overland flow along the floor of the valley into the largest of the three ponds. This does not follow the alignment of the channel of the Culworth Brook nor does it follow the extents shown on the Environment Agency FMfSW. The Proposed Scheme will maintain this connectivity with the large pond by the inclusion of a culvert. Upstream of the culvert there is an area of replacement floodplain storage that will provide sufficient land to alter the alignment of the channel and to mitigate for the loss of floodplain storage by the embankment.

8.2.13 In addition, downstream of the Thorpe Mandeville embankment a large area has been set aside at the eastern extent of the large pond to allow for re-profiling of the pond to increase storage. This will mitigate for any loss of flood storage as a result of the Thorpe Mandeville Embankment intruding into the pond.

8.2.14 The Thorpe Mandeville embankment is shown to also cross the area where flood water in the leat flows overland to the south towards the main channel of the Culworth Brook. Channel works will be undertaken on the leat to prevent the overland flow in this location. The main channel of the Culworth Brook will be decommissioned as the Thorpe Mandeville embankment will cover a significant length. Downstream works will be required to enhance the connection between the leat and the main channel of the Culworth Brook.

8.2.15 The exact course of the culvert of the Culworth Brook beneath Banbury Lane is not known. A closed-circuit television (CCTV) survey will be undertaken of the culvert to determine its exact location and ensure that there will be no interaction between the foundations of the viaduct piers and the culvert.

8.2.16 Sufficient replacement floodplain compensation will be provided at Lower Thorpe and therefore it is expected that there will be no significant effect on the risk of flooding.

River Cherwell

Description

8.2.17 The Proposed Scheme will cross the River Cherwell and two of its tributaries immediately downstream of Trafford Bridge, near Edgcote. The southern tributary flows parallel to the Proposed Scheme on the west side for approximately 1km with the route crossing the watercourse immediately prior to the confluence with the River Cherwell. Downstream of Trafford Bridge the Cherwell flows parallel to the Proposed Scheme on the east side for approximately 100m before turning west as the route will cross the main channel. The River Cherwell then flows parallel to the Proposed Scheme on the west side for a distance of approximately 300m before turning away to the west. A second tributary flows into the Cherwell from the north and is intersected by the Proposed Scheme shortly before the confluence. The Proposed Scheme will span the combined floodplains of the southern tributary and River Cherwell on viaduct, however the route will be on embankment at the crossing of the northern tributary, including the corresponding flood zones.

Local receptors and land use

8.2.18 Formal receptors within the 1km buffer extent that could be affected by the Proposed Scheme around Edgcote are Culworth Mill, Edgcote Mill and Home Farm. Culworth Mill is approximately 300m upstream of Edgcote viaduct, while Edgcote Mill and Home Farm are approximately 1km downstream.

8.2.19 The land use in the floodplain in the vicinity of the crossing is arable farm land, pasture and woodland. There are two public roads: Welsh Road and Mill Lane within the floodplain around Trafford Bridge.

Potential effects

8.2.20 The key design elements that have the potential to affect flood flows in the watercourses around Edgcote are the Edgcote viaduct, which will directly affect the River Cherwell and its southern tributary, and the Edgcote North embankment which will directly affect the northern tributary.

8.2.21 Edgcote viaduct will be 540m in length with typical span lengths of 20m. Span lengths vary in the vicinity of the watercourses to avoid placing piers directly within the channel of the River Cherwell. One pier will obstruct the channel of the southern tributary and, whilst there will be no additional piers within the watercourses themselves, at least three of the viaduct piers will lie on the top of bank of the River Cherwell with an additional eight piers falling within 8m of the top of bank of either watercourse. Viaduct piers within the floodplain will potentially obstruct flood flows leading to increases in flood water levels in the area, particularly when the cumulative impact of each pier is considered, since the viaduct passes along the valley bottom parallel to the direction of floodplain flow. Some viaduct piers will be located directly on the top of bank, where flood water velocities are generally highest, exacerbating any impact due to flood flow obstruction. Each viaduct pier will additionally displace flood water, leading to further potential increases in surrounding flood water levels.

8.2.22 The Edgcote North embankment will cross the floodplain of a second tributary of the River Cherwell approximately 150m upstream of the confluence. Although a culvert will be installed to convey flows in this watercourse the embankment will alter flow mechanics and potential influence flood water levels in the area.

8.2.23 Due to the complexity of the potential impact on flood risk around Culworth and Edgcote resulting from the Proposed Scheme and, due to the lack of previously available hydraulic model information, detailed hydraulic modelling has been carried out to assess the impact of the Proposed Scheme.

Assessment of effects

8.2.24 Hydraulic modelling has been undertaken for the River Cherwell at Edgcote using the hydraulic modelling software SMS TUFLOW. The purpose of this hydraulic model was to assess the impact of the viaduct piers of the flood water levels within the floodplain of the River Cherwell. A more detailed description of the hydrology and the modelling methodology can be found in the River Cherwell hydraulic modelling report (Volume 5: Appendix WR-004-007). The hydraulic modelling results are show on Map WR-05-

038 and Map WR-06-038 (Volume 5, Water Resources and Flood Risk Assessment Map Book).

8.2.25 The hydraulic modelling of the River Cherwell at Edgcote focusses on the potential change in peak flood water levels due to the presence of piers within the floodplain. Baseline modelling was undertaken in order to represent the existing condition and the obstructions were then represented by blocking grid cells from the calculation at the location of each of pier. Modelled existing peak flood water levels were subtracted from Proposed Scheme results thereby providing the increase in flood depth as a result of afflux due to the viaduct piers.

8.2.26 There was found to be a maximum increase of 20mm in flood depth for the 1 in 100 years return period (1% annual probability) flood event including an allowance for climate change. The location which shows the largest predicted increase was upstream of each of the piers adjacent to the watercourse. The increase in the depth of flooding reduces to approximately 10mm upstream of Trafford Bridge. In lower return periods (the modelled 1 in 20 years return period) there is shown to be no impact upstream of Welsh Road. More information on the results of the hydraulic modelling for the River Cherwell can be found in Volume 5: Appendix WR-004-007.

8.2.27 Replacement floodplain storage will be provided to mitigate for any loss of floodplain storage as a result of the viaduct piers. Due to the afflux caused by the viaduct piers there will be a localised minor impact on the risk of flooding to the moderate value receptor of the adjacent agricultural land, resulting in a slight adverse effect. This effect will not be significant.

Highfurlong Brook

Description

8.2.28 The Proposed Scheme will cross the Highfurlong Brook and floodplain to the west of Aston le Walls with the floodplain spanned on viaduct. Although the brook is tightly meandering in the area of the Proposed Scheme the channel will only be crossed once and the route will cross the floodplain perpendicular to the flow direction. There is a small surface lake within the floodplain to the east of the river where the Proposed Scheme will cross the watercourse. This does not, however, appear to be hydraulically connected to the Highfurlong Brook under normal flow conditions.

Local receptors and land use

8.2.29 Bridge Meadow, an agricultural building approximately 1km upstream of the Proposed Scheme, is the only formal receptor within the study area that could be affected by the Proposed Scheme along the Highfurlong Brook valley.

8.2.30 The land use in the floodplain upstream of the Proposed Scheme is arable farm land and pasture, together with the leisure facilities of the Aston le Walls equestrian centre at Washbrook Farm.

Potential effects

8.2.31 The key design elements that have the potential to affect flood flows in the Highfurlong Brook are the Highfurlong Brook viaduct and approach embankments.

The viaduct will be supported on seven piers located at 20m centres with the first and last spans being 15m. Approximately 30m of the floodplain width will be obstructed by the southern abutment and 10m by the northern abutment. Since viaduct piers are proposed within the floodplain flow area, and solid construction is proposed at the edges of the floodplain, the Proposed Scheme will potentially obstruct floodplain flows which could lead to increased water levels upstream of the Proposed Scheme. Each viaduct pier will additionally displace flood water leading to further potential increases in surrounding flood water levels.

Assessment of effects

8.2.32 The effect of the Highfurlong Brook viaduct on flood water levels in the Highfurlong Brook was estimated as part of the Proposed Scheme design through the use of "conceptual" one-dimensional hydraulic modelling. Hydraulic modelling was undertaken to determine baseline and post-development flood water levels taking into account the restriction to floodplain width imposed by the two abutments. The hydraulic modelling results for the Culworth Brook are show on Map WR-05-040 and Map WR-06-040 (Volume 5, Water Resources and Flood Risk Assessment Map Book).

8.2.33 The baseline estimates of maximum flood water levels at the crossing are presented in Table 7. The minimum top of rail level will be 113.0m AOD and the viaduct deck (rail to soffit) will be 2m deep resulting in a minimum soffit level of 111.0m AOD. The viaduct deck will clear the floodplain with a freeboard between the estimated 1 in 1,000 years return period (0.1% annual probability) flood water level and the minimum soffit of 2.6m.

Table 7: Estimated flood water levels in the Highfurlong Brook

	100 years return period	**100 years return period including climate change**	**1,000 years return period**
Baseline	107.41m AOD	107.45m AOD	107.54m AOD
Future	107.43m AOD	107.46m AOD	107.56m AOD
Afflux	20mm	10mm	20mm
Maximum Influence	<150m	<150m	<50m

8.2.34 No viaduct piers will be located within the channel of the Highfurlong Brook and the viaduct will be perpendicular to the floodplain flow direction. According to the ISIS hydraulic modelling of the 1 in 1,000 years return period (0.1% annual probability) event peak velocities in the channel are 0.9m/s at bank full, with a peak of 0.77m/s (averaged across the floodplain) once out of bank flooding occurs. Corresponding maximum flood depths are approximately 700mm. According to the model the proposed viaduct results in an increase in upstream flood water levels of 10mm in the 1 in 100 years return period (1% annual probability) event including climate change, and an increase of 20mm in the 1 in 1,000 years return period (0.1% annual probability) event. The viaduct impact will extend to a maximum of 150m upstream.

8.2.35 The viaduct piers will be formed of double columns, each with a plan area of 9m^2 i.e. with a total plan area of 18m^2 at each support. Abutment footprint areas within the floodplain will be approximately 1,000m^2 and 200m^2 to the south and north of the floodplain respectively. Regardless of the impact of the viaduct piers on the dynamic characteristics of the floodplain the built volume within the floodplain will cause displacement of flood water through the removal of floodplain storage.

8.2.36 Replacement floodplain storage will be provided to mitigate for any loss of floodplain storage as a result of the viaduct piers. Due to the afflux caused by the viaduct piers there will be a localised minor impact on the risk of flooding to the moderate value receptor of the adjacent agricultural land, resulting in a slight adverse effect. This effect will not be significant.

Summary of effects

8.2.37 The hydraulic modelling and afflux calculations undertaken shows that the Proposed Scheme will result in a minor impact on the risk of flooding in the immediate vicinity of the viaduct due to the hydrodynamic effects of the viaduct piers and reduced floodplain width. Floodwater displacement due to the viaduct piers and abutments will also occur.

8.2.38 The single identified receptor within the Highfurlong Brook floodplain, Bridge Meadow, will not experience any adverse effect on the risk of flooding from the Highfurlong Brook as a result of the Proposed Scheme due to the distance upstream of the constriction. The calculated afflux effects will extend a maximum of 150m upstream of the Proposed Scheme viaduct crossing resulting in minor increases in floodwater levels on land belonging to Washbrook Farm on the south side of the watercourse, and Paradise Farm and Cleveland Farm on the north side of the watercourse.

8.3 Impact on risk of flooding from surface water

Radstone

8.3.1 At the southern extent of the study area the Proposed Scheme will cross a small watercourse and dry valley within land currently belonging to Halse Grange Farm. The FMfSW shows 'deep' surface water flooding in the 1 in 30 years return period (3.3% annual probability) rainfall event at the watercourse crossing and 'shallow' surface water flooding in the 1 in 30 years return period (3.3% annual probability) rainfall event at the northern dry valley.

8.3.2 The Proposed Scheme will be on a low embankment at the watercourse crossing and at grade within the dry valley. Surface water flows in the dry valley on both sides of the Proposed Scheme will be collected and discharged to the watercourse which will then be conveyed beneath the Proposed Scheme in a 1350mm diameter culvert. This culvert has been designed to convey a flow of 2.01m^3/s which is the calculated combined peak 1 in 100 years return period (1% annual probability) flow including an allowance for climate change from this watercourse, and a second tributary of the Radstone Brook which will be intercepted by the Proposed Scheme approximately 500m to the south.

8.3.3 The dry valley will additionally be obstructed by the embankments of a PRoW overbridge which is proposed to cross the rail lines at the same location. Two 1350mm culverts, one on the east side and one on the west side, will be included within the overbridge embankments to maintain continuity of flows to the watercourse.

8.3.4 In the present undeveloped scenario the dry valley and watercourse combine approximately 40m downstream of the location of the Proposed Scheme crossing. By combining flows upstream of the route, a slight increase in flows within the watercourse channel for this 40m stretch could potentially lead to a slightly increased risk of channel capacity exceedance. Due to the scale of flows, however, any such increase is likely to be negligible. Likewise, potential reductions in floodwater conveyance time within the vicinity of the Proposed Scheme due to channel straightening and culverting are expected to be negligible and consequently will not significantly affect the risk of flooding arising from downstream sources such as the Radstone Brook.

Greatworth Fields

8.3.5 To the east of Greatworth Fields the Proposed Scheme will cross a dry valley within land currently belonging to Greatworth Hall Farm. The FMfSW shows the base of the valley, to a distance of approximately 40m upstream of the Proposed Scheme, to be at risk of "shallow" flooding in the 1 in 200 years return period (0.5% annual probability) rainfall event. Although the Proposed Scheme will be in a shallow cutting at this location there is sufficient room for a drop inlet culvert of 1350mm diameter designed to convey the calculated 1 in 100 years return period (1% annual probability) flow including an allowance for climate change (0.62m^3/s) plus allowances for siltation and blockage. As a result there will be no significant increase in the flood risk upstream of the Proposed Scheme. Any potential reductions in floodwater conveyance time within the vicinity of the Proposed Scheme due to channel straightening and culverting are expected to be negligible and consequently will not significantly affect the risk of flooding arising from downstream sources such as the watercourses around Halse and Steane.

Greatworth Hall

8.3.6 To the east of Greatworth the Proposed Scheme will cross a dry valley within land currently belonging to Greatworth Hall Farm. The FMfSW shows the base of the valley, to a distance of approximately 60m upstream of the Proposed Scheme, to be at risk of 'shallow' flooding in the 1 in 200 years return period (0.5% annual probability) rainfall event. The Proposed Scheme will be on a low embankment at this location and a 1350mm diameter culvert will be provided, designed to convey the calculated 1 in 100 years return period (1% annual probability) flow including an allowance for climate change (0.62m^3/s), siltation and blockage. As a result there will be no significant increase in the flood risk upstream of the Proposed Scheme. Any potential reductions in floodwater conveyance time within the vicinity of the Proposed Scheme due to channel straightening and culverting are likely to be negligible and consequently will not significantly affect the risk of flooding arising from downstream sources such as the watercourses around Steane and Brackley.

Painter's Spinney

8.3.7 West of Painter's Spinney the Proposed Scheme will cross a dry valley within land currently belonging to the Marston St Lawrence Estate. The FMfSW shows the base of the valley, to a distance of approximately 40m upstream of the Proposed Scheme, to be at risk of 'shallow' flooding in the 1 in 200 years return period (0.5% annual probability) rainfall event. The Proposed Scheme will be below ground, in tunnel, at this location and existing topography will be restored following construction of the green tunnel. Therefore, there will be no change in the topography or land use resulting from the Proposed Scheme. There will be no change in the flood risk upstream or downstream of the Proposed Scheme and consequently there will not be a significant effect on the risk of flooding arising from downstream sources such as the watercourses through Stuchbury and Helmdon.

Costow Farm

8.3.8 East of Costow House the Proposed Scheme will cross a dry valley and source of a small stream within land currently belonging to Costow Farm. The FMfSW shows the base of the valley to be at risk of 'shallow' flooding in the 1 in 30 years return period (3.3% annual probability) rainfall event and 'deep' flooding in the 1 in 200 years return period (0.5% annual probability) rainfall event. There is a risk of surface water flooding shown to a distance of approximately 550m upstream of the Proposed Scheme. The Proposed Scheme will be in deep cutting at the valley crossing at the north portal of the Greatworth green tunnel and will include the creation of a diverted runoff pathway along the east side of the Proposed Scheme, discharging to the ponds at Lower Thorpe. The catchment size at Costow House, downstream of the Proposed Scheme, is 0.5km^2, with a corresponding 1 in 100 years return period (1% annual probability) peak flood flow (including a 30% allowance for climate change) of 0.8m^3/s.

8.3.9 The FMfSW shows the extent of flooding due to rainfall that is predicted to occur prior to collection of water into streams or designated drainage infrastructure. By collecting the flows into an adequately designed land drainage system the Proposed Scheme will effectively remove the risk of surface water flooding from the point at which the flow is intercepted. In addition the area of catchment upstream of the Proposed Scheme will be removed from the watercourse system downstream of the Proposed Scheme to Lower Thorpe, where the diversion is returned to the catchment. As a result there will potentially be a slight reduction in the risk of flooding at Costow House and Bulls Lane sewage works due to reduced overall rainfall volumes, although this reduction is not expected to be significant.

8.3.10 Any potential reductions in floodwater conveyance time due to the diversion along the east side of the Proposed Scheme will potentially affect the risk of flooding arising from the continuing watercourse at Lower Thorpe downstream. Since the catchment and flows involved are relatively small, however and since the diversion will discharge directly to the lake (which has a plan area of approximately 10,000m^2) this effect is not expected to be significant.

Lower Thorpe

8.3.11 From north-east of Thorpe Mandeville to Lower Thorpe the Proposed Scheme will cross an area shown on the FMfSW to be at risk of 'deep' surface water flooding in the 1 in 30 years return period (3.3% annual probability) rainfall event along the natural valley.

8.3.12 The assessment of the impact on the risk of flooding at Lower Thorpe has been considered under the assessment of river flooding from the Culworth Brook.

Banbury branch line

8.3.13 Approximately 500m north-west of Lower Thorpe the Proposed Scheme will cross a small stream within land currently belonging to Culworth Grounds Farm. The Proposed Scheme will cross the watercourse immediately downstream of an existing viaduct which formerly carried the Great Central Main Line Banbury Branch across the watercourse. The FMfSW indicates a risk of 'deep' flooding in the 1 in 30 years return period (3.3% annual probability) rainfall event along the base of the valley. There is a risk of surface water flooding shown to a distance of approximately 1km upstream of the Proposed Scheme, as far as Hill Farm.

8.3.14 The Proposed Scheme will be on embankment across the valley. The stream will be diverted along the west side of the Proposed Scheme before being conveyed beneath the embankment in a 1350mm diameter culvert. Diversion of the watercourse will potentially create areas on the west side of the Proposed Scheme to the south of the existing embankment with an increased risk of ponding during rainfall events. Design of the channel diversion and culvert, however, has been undertaken to ensure adequate capacity to convey the 1 in 100 years return period (1% annual probability) rainfall event, including an allowance for climate change.

8.3.15 Any potential reductions in floodwater conveyance time within the vicinity of the Proposed Scheme due to channel straightening and culverting are expected to be negligible and consequently will not significantly affect the risk of flooding arising from the continuing watercourse or the River Cherwell downstream.

Danes Moor

8.3.16 To the east of Danes Moor the Proposed Scheme will cross the route of a public bridleway. The southern approach embankment for the proposed overbridge will cross a dry valley within land currently belonging to West Mill Farm. The FMfSW shows the base of the valley to be at risk of 'shallow' flooding in both the 1 in 30 years and 1 in 200 years return period (3.3% and 0.5% annual probability) rainfall events. There is a risk of surface water flooding shown to a distance of approximately 250m upstream of the Proposed Scheme.

8.3.17 A culvert through the proposed embankment will be provided designed to convey the calculated 1 in 100 years return period (1% annual probability) flow including an allowance for climate change, as well as allowances for siltation and blockage. As a result there will be no significant increase in the flood risk upstream of the Proposed Scheme. Due to the extremely short length of the crossing (maximum 13m) any potential reductions in floodwater conveyance time within the vicinity of the

Proposed Scheme will be negligible and consequently will not significantly affect the risk of flooding arising from downstream watercourses.

River Cherwell

8.3.18 The FMfSW indicates areas of 'deep' flooding along the valley of the River Cherwell in the 1 in 30 years return period (3.3% annual probability) rainfall event prior to surface water runoff reaching the channel. The impact on the risk of flooding at this location has been considered in the assessment of river flooding from the River Cherwell.

Highfurlong Brook

8.3.19 The FMfSW indicates areas of 'deep' flooding along the valley of the Highfurlong Brook in the 1 in 30 years return period (3.3% annual probability) rainfall event prior to surface water runoff reaching the channel. The extents of flooding shown are within the flood zone extents for the watercourse and, since flooding from direct surface water runoff occurs early in any given rainfall event, is likely to have receded prior to the onset of any significant flooding from the watercourse. On this basis there is unlikely to be any significant cumulative effect due to combined flooding from surface water runoff and from the watercourse that is not already accounted for in the analysis of the Highfurlong Brook described in Section 8.2 of this report. Consequently, there will be no increase in the severity of the effect of the Proposed Scheme on the risk of flooding within the Highfurlong Brook valley and any mitigation proposed to offset the minor effects on the severity of flooding from the watercourse will equally serve to counteract any minor effects on flooding from this source.

Hill Road

8.3.20 To the south of Lower Boddington the Proposed Scheme will cross a dry valley which lies along the western edge of Hill Road. There is a watercourse that runs along the eastern edge of Hill Road, which collects surface water runoff from the east, however the dry valley receives all surface water runoff from the slopes to the west of the road. The FMfSW indicates a risk of 'shallow' surface water flooding in both the 1 in 30 years and 1 in 200 years return period (3.3% and 0.5% annual probability) rainfall events within this dry valley. In addition to the cutting the Proposed Scheme will incorporate a new overbridge for Hill Road, with raised earth approach embankments.

8.3.21 The existing stream on the east side of the road will be diverted along the foot of the Hill Road approach embankments, and conveyed beneath the Proposed Scheme in an inverted siphon. There are no FMfSW extents associated with the stream.

8.3.22 There will be no formal means provided to maintain continuity of flows overland along the dry valley. This could potentially lead to surface water runoff ponding upstream of the Proposed Scheme alongside Hill Road in the area between the Proposed Scheme and the Boddington Reservoir canal feeder, on land currently owned by Cedar House Farm. In addition landscaped noise barriers will be constructed along both sides of the route which will result in the displacement and redirection of surface water runoff, with an approximate plan area of 10,000m^2 displaced according to a comparison between the Proposed Scheme footprint and the FMfSW 200 years return period outline. Thus, a volume of up to 3,000m^3 could potentially be redirected onto surround land as a result of the Proposed Scheme. It is not anticipated that any formal

receptors will be affected by this displacement which will largely result in ponding on agricultural land belonging to Cedar House Farm.

8.3.23 It is likely that any such ponding or increase in surface flow volumes will occur upstream of the Proposed Scheme, with downstream flows following alternative routes to the existing valley bottoms and flow paths. Consequently, the risk of surface water flooding at Springfield House, which lies downstream of the route, is likely to remain unchanged as a result of this dry valley crossing.

Cedar House Farm

8.3.24 Approximately 650m west of Lower Boddington, between Cedar House Farm and Fir Tree House, the Proposed Scheme will cross a dry valley within land currently belonging to Cedar House Farm. The FMfSW shows a risk of 'shallow' surface water flooding in both the 1 in 30 years and 1 in 200 years return period (3.3% and 0.5% annual probability) rainfall events. The dry valley at this location is particularly well defined and ultimately forms the Springfield Brook, a tributary of the Wormleigh Brook, around 1.6km downstream of the Proposed Scheme.

8.3.25 Around 200m upstream of the Proposed Scheme, alongside Banbury Road, the dry valley is crossed by the Boddington Reservoir canal feeder. It is likely that this artificial watercourse intercepts the majority of flows upstream of this point and ground level information suggests that there is a bund on the downstream side of the canal feeder preventing further overland flow to the south. Consequently, the extent of the FMfSW may be over-estimated downstream of Banbury Road.

8.3.26 A culvert will be provided to maintain continuity of flows overland along the base of the dry valley included within the Proposed Scheme. On the west side of the Proposed Scheme, so long as the noise barriers and surface water drainage are appropriately designed, the downstream effects on the risk of surface water flooding will be negligible especially when combined with the reduction in overall surface water runoff volumes resulting from the redirection of flows on the east side of the Proposed Scheme. As a result no adverse impact on the risk of flooding from surface water is expected at Springfield House, which is the only formal downstream receptor.

Three Shires

8.3.27 West of Lower Boddington, the Proposed Scheme will cross the Boddington Reservoir canal feeder. There is a watercourse running parallel to the Proposed Scheme on the west side which joins the Canal Feeder immediately downstream of the Proposed Scheme. The FMfSW shows areas along this valley, which lies within the current ownership of Three Shires Farm and Hill Farm, Collins Farm, Spella Bungalow and Cedar House Farm, with a risk of 'shallow' surface water flooding in both the 1 in 30 years and 1 in 200 years return period (3.3% and 0.5% annual probability) rainfall events. Although the route does not cross this valley, and is not therefore considered to be at risk from this source, noise barriers are proposed across the valley on both sides of Boddington Road, which will obstruct the natural overland flow pathways.

8.3.28 According to a comparison between the Proposed Scheme footprint and the FMfSW 200 years return period outline an approximate plan area of 19,000m^2 will be

displaced by the noise barriers. Thus, a volume of up to 5,700m^3 will potentially be redirected onto surrounding land as a result of the Proposed Scheme.

8.3.29 The stream will be diverted around the western edge of the noise barriers, up to 200m south west of the present course. The diversion and associated re-grading works will relocate the areas of surface water flood risk towards Three Shires Farm. It is not anticipated that any formal receptors will be affected by this displacement which will largely result in increased potential for flooding on agricultural land belonging to Three Shires Farm (west of Boddington Road) and Cedar House Farm (east of Boddington Road). Since, however, the stream diversion will be designed with sufficient channel capacity for the 1 in 100 years return period (1% annual probability) flood event including an allowance for climate change, potential for ponding along the new valley will be minimised.

8.4 Impact on risk of flooding from groundwater

8.4.1 The Proposed Scheme is not expected to have any long-term impacts on groundwater levels within the bedrock aquifers within the study area. Localised effects within the superficial deposits at cuttings and the Greatworth and Chipping Warden green tunnels will potentially be observed and are detailed within the CFA14 Water Resources Assessment (Volume 5: Appendix WR-002-015).

8.4.2 From Greatworth to Lower Thorpe groundwater flow is generally along the line of the Proposed Scheme and no significant effects are expected. Groundwater levels along the east side of the Proposed Scheme north of Chipping Warden may be slightly elevated due to obstruction of southerly flows within the superficial aquifer.

8.4.3 There are areas of low and very low susceptibility to groundwater emergence from the bedrock aquifers on the east side of the Proposed Scheme from Calves Close Spinney to the disused airfield. Due to the shallow depths of cutting relative to the extent of the bedrock aquifers the impact of the Proposed Scheme is expected to be extremely low. Nevertheless, were groundwater levels to rise as a result of the Proposed Scheme, ground levels suggest that any flooding due to groundwater emergence would flow north and discharge via the River Cherwell tributary on the east side of the route. There are no vulnerable receptors within the area at risk.

8.4.4 There is a second area of very low susceptibility to groundwater emergence from the bedrock aquifers running along the north side of Appletree Lane, and extending into Aston le Walls. It is similarly unlikely that groundwater levels will rise within the bedrock aquifers to increase the risk of groundwater emergence such that any flooding would be expected. Topography in the area is steep and undulating and any groundwater emergence would discharge overland to the Highfurlong Brook, or, within the Aston le Walls urban area, be collected into surface water drainage systems.

8.4.5 There are three locations within the study area where the Proposed Scheme intersects areas with a moderate or greater susceptibility to groundwater flooding. All three locations relate to potentially high groundwater levels within superficial alluvial deposits. Along the valleys of the River Cherwell and Highfurlong Brook, the Proposed

Scheme will be on viaduct and is not expected to significantly influence groundwater flows or levels.

Halse Copse

8.4.6 The Proposed Scheme will be in shallow cutting at the intersection with the area of very high susceptibility to groundwater flooding. The area at risk is less than 50,000m^2 in plan area (of which only 13,000m^3 lies upstream of the Proposed Scheme), and lies along the base of a river valley. Susceptibility to groundwater flooding in this area arises from superficial deposits. It is likely that potential for groundwater flooding within this area is closely linked with the watercourse, the spring of which is approximately 150m upstream of the Proposed Scheme. Continuity of the watercourse will be maintained through provision of a culvert and it is anticipated that the surface water collection system proposed as part of the Proposed Scheme will collect any emergent groundwater into the watercourse. It is likely that the impact on the risk of flooding from this source will therefore be negligible.

8.5 Impact on risk of flooding from drainage systems

8.5.1 With the exception of Lower Thorpe the Proposed Scheme will not pass through any urban areas for the full extent within the study area. At Lower Thorpe the route will be on viaduct and is not anticipated to interfere with drainage infrastructure in the area. As a result no impact on the risk of flooding from drainage systems is expected.

8.5.2 All highway crossings required will be diverted or re-designed as bridges or underpasses, with the exception of those that will be crossed on viaduct which will remain unchanged. Highway drainage for all new or realigned roads will be designed in accordance with the relevant design guides and regulations and consequently no increase in the risk of flooding arising from overloaded highway drains is anticipated.

8.6 Impact on risk of flooding from artificial sources

8.6.1 Where the Proposed Scheme will cross the area with a residual risk of impounded reservoir failure it will be on embankment and viaduct for the crossing of the Highfurlong Brook. The modelled extent of the residual risk of reservoir failure is shown to be greater than the extent of the flood zones of the Highfurlong Brook. The length of the viaduct has been designed to span the floodplain and therefore embankments will be constructed within the reservoir flood risk area.

8.6.2 The Environment Agency reservoir inundation mapping only displays the residual risk of failure of artificial water bodies with a capacity above 25,000m^3 which are covered under the Reservoirs Act 1975 (as amended). This requires water companies to maintain their reservoirs such that the annual probability of a breach of the reservoir is 1 in 50,000. There is a potential impact on the residual risk of flooding from the reservoir, however, this water body is subject to the requirements of the Reservoirs Act and the likelihood of such flooding occurring is extremely low. Mitigation measures employed against the potential impact on flooding from the Highfurlong Brook will additionally apply to the risk of flooding from the Boddington Reservoir. The impact of the Proposed Scheme on the actual risk of flooding from impounded reservoir failure will be negligible.

8.7 Summary of potential impacts and effects on flood risk

Table 8: Summary of potential flood risk impacts and effects in CFA15

Receptor	Vulnerability classification	Pathway	Impacts and effects
General Proposed Scheme	N/A	River flooding	No significant effects expected at Lower Thorpe. Minor afflux and volume displacement at Edgcote viaduct. Minor afflux and volume displacement at Highfurlong Brook viaduct.
		Surface water	Diversion of surface water flows upstream of Thorpe Mandeville cutting will potentially reduce downstream risks. Interruption of dry valleys and land raising west of Lower Boddington will potentially result in increased runoff to Boddington reservoir canal feeder and/or displacement of floodwater onto surrounding ground.
		Groundwater	No significant effects expected.
		Drainage systems	No effects expected.
		Artificial sources	Potential minor afflux upstream of Highfurlong Brook viaduct in the event of failure of the Boddington reservoir.
Costow House (access track)	More vulnerable	Surface water 30 years - deep	Upstream effects expected to be negligible due to high gradients and distance of Proposed Scheme to receptor.
Sewage works at Bulls Lane	Less vulnerable	Surface water 30 years - deep	Upstream effects expected to be negligible due to high gradients and distance of Proposed Scheme to receptor.
Thorpe Mandeville village	More vulnerable	Surface water 30 years - shallow	Upstream effects expected to be negligible due to high gradients and distance of Proposed Scheme to receptor.
Lower Thorpe hamlet	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - deep	No significant effects expected.
Lower Thorpe Farm	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - deep	No significant effects expected.
Wadground Barn	Less vulnerable	Surface water 30 years - deep	No significant effects expected.

Receptor	Vulnerability classification	Pathway	Impacts and effects
Culworth Mill	More vulnerable	River flooding Flood Zone 2 Surface water 200 years - shallow Groundwater - high	The predicted afflux that will result from the Edgcote viaduct will extend a maximum of 150m upstream. Edgcote Mill and Home Farm will therefore not be adversely affected by the Proposed Scheme.
Mill Lane	Water compatible	Surface water 30 years - deep	The predicted afflux that will result from the Edgcote viaduct will extend a maximum of 150m upstream. Edgcote Mill and Home Farm will therefore not be adversely affected by the Proposed Scheme.
Edgcote Mill and Home Farm	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - deep Groundwater - high	No significant effects expected.
Bridge Meadow	Less vulnerable	River flooding Flood Zone 3 Surface water 30 years - deep Boddington Reservoir. Groundwater - high	The predicted afflux that will result from the Highfurlong Brook viaduct will extend a maximum of 150m upstream. Bridge Meadow will therefore not be adversely affected by the Proposed Scheme.
Springfield House	More vulnerable	Surface water 30 years - shallow	Proposed Scheme will redirect flows into Boddington Feeder and potentially slightly reduce downstream surface water flooding extents.
Cedar House Farm (access track)	More vulnerable	Surface water 30 years - shallow	Noise barriers will significantly alter the topography of the area, and redirect flows to the Boddington Feeder. The access track will be rebuilt under the Proposed Scheme and will be designed not to flood.
Firtree Nurseries	Less vulnerable	Surface water 30 years - shallow	Firtree Nurseries to be demolished. Proposed Scheme will divert the watercourse and shift the valley south, away from Firtree House and Nursery.

9 Conclusions

9.1 Summary

9.1.1 The Proposed Scheme within CFA15 extends from 1km north-east of Halse in an approximately south-east to north-west direction to 2km west of Upper Boddington. The study area includes all areas within 1km of the Proposed Scheme which includes areas at risk of flooding from various sources, as follows:

- areas at risk of river flooding from the River Cherwell, the Culworth Brook at Lower Thorpe and the Highfurlong Brook;
- areas at risk of flooding arising from direct runoff of rainfall, together with five minor watercourse crossings;
- areas susceptible to groundwater emergence within superficial deposits and thus at risk of groundwater flooding, one of which coincides with an area of below ground level construction;
- Lower Thorpe hamlet, where private and local surface water management systems may pose a risk of flooding; and
- an area at risk of inundation should the Boddington reservoir fail.

9.1.2 The Proposed Scheme will be at least 1m above design flood water levels within all areas at risk of flooding from rivers, drainage and artificial sources. Residual risks from these sources will be negligible. There are some areas at risk of flooding from direct surface water runoff where the Proposed Scheme will be less than 1m above ground levels, resulting in a need for greater consideration of the risk of flooding when designing surface water management schemes and watercourse crossings. There is one instance where the Proposed Scheme will be in shallow cutting through an area with a very high susceptibility to groundwater emergence. In this case the area of risk coincides with a dry valley and minor watercourse and any groundwater flooding will be collected into the surface water land drainage. Design standards are such that no flooding of the Proposed Scheme is expected under normal operating conditions.

9.1.3 The dominant land use within the study area is rural agriculture. Excluding areas of farmland adjacent to the Proposed Scheme there are no third party receptors that will be significantly affected by the Proposed Scheme.

9.1.4 Hydraulic modelling was undertaken for the Culworth Brook at Lower Thorpe to confirm the extent of flooding upstream of the Thorpe Mandeville embankment. Hydraulic modelling was also undertaken to assess the afflux due to the viaduct piers on the River Cherwell at Edgcote.

9.2 Residual flood risks to Proposed Scheme

9.2.1 Residual flood risks arise in situations that are not included in standard design scenarios, for example when a culvert becomes blocked causing flooding upstream. All design is generally undertaken assuming that existing infrastructure is functioning

under normal conditions. Consequently, there may be areas where the potential severity of flooding may exceed the design standard under certain circumstances.

Residual flood risks from rivers

Lower Thorpe

9.2.2 There are a number of existing hydraulic structures at Lower Thorpe including the culvert beneath Banbury Lane. Although a blockage of this culvert could cause an increase in the depth of flooding upstream the viaduct will be some 8.5m above the floodplain, and the residual risks of flooding over and above the design event would not be significant.

River Cherwell

9.2.3 There are two existing hydraulic structures in the vicinity of the River Cherwell crossing, Trafford Bridge and the culvert which conveys the southern tributary under Mill Road. Trafford Bridge is upstream of the Proposed Scheme and blockage of the culvert will not lead to any significant increase in the risk of flooding to the Proposed Scheme, with any increase in severity likely to occur upstream around Culworth Mill. Trafford Bridge currently restricts flows within the Cherwell around the Proposed Scheme and any collapse of the bridge could potentially cause minor increases in flood water levels downstream. Blockage of the culvert beneath Mill Road is not expected to cause any significant increase in flood water levels which would be dominated by the much larger River Cherwell. The viaduct will be approximately 7m above the floodplain, and the residual risks of flooding over and above the design event would not be significant.

Highfurlong Brook

9.2.4 There are no significant hydraulic structures within the vicinity of the Proposed Scheme that would create additional residual risks to the Proposed Scheme.

Residual flood risks from surface water and minor watercourses

9.2.5 All culverts within the Proposed Scheme are designed with a minimum internal headroom of 300mm above the design flood water level to minimise the risk of blockage. There is therefore not expected to be any significant increased risk of flooding at minor watercourses and dry valley crossings arising from potential blockage of new culverts.

9.2.6 Inverted siphons are used in the design, which are prone to blockage and require regular maintenance. Siphons are only used where all other alternative structures have been deemed unfeasible. There is a residual flood risk arising to the Proposed Scheme in the event of blockage within the inverted siphon at Hill Road.

9.2.7 Other than at Lower Thorpe, there are no watercourse crossings within the study area where significant existing hydraulic structures are present within a reasonable hydraulic distance either upstream or downstream. There are no further residual risks of flooding to the Proposed Scheme from surface water runoff or minor watercourses.

Residual flood risks from groundwater

9.2.8 Groundwater levels rise and fall relatively slowly, and for any change to occur in the risk of flooding from this source, below ground intervention is necessarily required. The risk of flooding from groundwater already considered therefore presents an absolute risk, and there are no significant residual risks arising from this source.

Residual flood risks from drainage systems

9.2.9 Blockage of underground surface water collections systems can cause surcharge and associated flooding. Other than at Lower Thorpe there are no risks of flooding to the Proposed Scheme from drainage systems associated with existing infrastructure within the study area. At Lower Thorpe existing sewer infrastructure may need diverting, but any replacement infrastructure will be to at least the same standard as existing. Consequently, no additional residual risk to the Proposed Scheme is expected as a result of drainage system failure.

Residual flood risks from artificial sources

9.2.10 Within the study area the only flood risk to the Proposed Scheme arising from artificial sources is the inundation area associated with failure of the Boddington reservoir. The inundation mapping considers the potential for total failure of the reservoir, with the entire impounded volume released. Consequently, no further residual risks arise from this source.

9.3 Residual effects of the Proposed Scheme on flood risk

9.3.1 Following mitigation for impacts on the risk of flooding arising from the Proposed Scheme, there will be slight residual effects on the risk of flooding due to changes to geometry, floodplain flow characteristics and river and floodplain morphology at the Culworth Brook crossing at Lower Thorpe and the River Cherwell crossing at Edgcote. Such effects will be limited to the reshaping of floodplain extents arising from replacement floodplain storage and channel works, with no overall residual effects on third party receptors.

9.3.2 All culverts within the Proposed Scheme are designed to convey the 1 in 100 years return period (1% annual probability) flow including an allowance for climate change with a minimum internal headroom of 300mm above the design flood water level to minimise the risk of blockage. Consequently, there will be negligible increase in upstream residual flood risks arising from the introduction of culverts within the Proposed Scheme.

9.4 Compliance with local planning policy

9.4.1 The Proposed Scheme includes an allowance for future increases in the risk of flooding as a result of climate change by adding a 20% increase to design river flows and a 30% increase to rainfall intensities and flows in minor watercourses as recommended in the NPPF Technical Guidance document. SuDS, in the form of attenuation ponds and swales, as well as the creation of open channel land drainage, are used throughout the design. The Proposed Scheme will be in compliance with the

West Northamptonshire SFRA, West Northamptonshire Water Cycle Study and WNJPU Core Strategy.

9.4.2 Although not in direct contravention of the Thames Region CFMP, the inevitable losses in natural floodplain capacity and introduction of additional culverts is at variance with the general aims of the Thames catchment flood management plan which seeks to restore culverted watercourses and enhance natural floodplain. Where, however, losses in natural storage capacity are identified mitigation will be provided in the form of replacement floodplain storage. There is no practical way to avoid a certain amount of watercourse culverting and floodplain or valley flow obstruction, due to the nature of the Proposed Scheme. Due to the specific nature of the Northamptonshire LFRMS, the Proposed Scheme is in contravention of Policy 1 - no culverting of watercourses, Policy 4- no diversion or obstruction of watercourses and Policy 7 - no obstructions within 9m of the edge of any watercourse.

10 References

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